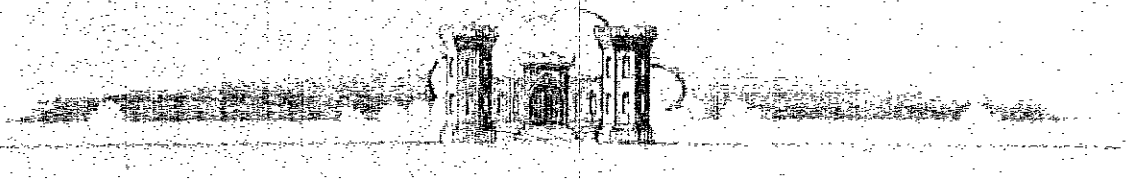
BEACH EROSION CONTROL REPORT
ON COOPERATIVE STUDY OF
METROPOLITAN DISTRICT COMMISSION BEACHES
MASSACHUSETTS

PART A

LYNN – NAHANT BEACH

JUNE 1, 1949



CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASSACHUSETTS

SYLLABUS - LYNN-NAHANT BEACH

The Division Engineer finds that the existing sea-walls extending from Blaney Rock to the bathing beach, although adequate for the protection of the coastal cliff are now endangered by the eroding beach and are in need of repair, and that the bathing beach south of the sea-walls is generally unsatisfactory for recreational purposes, and is too low to prevent storm waves attacking adjacent land areas. He also finds that there is danger of the Nahant tombolo, which extends from the bathing beach to Little Nahant, being breached by storm waves.

The Division Engineer recommends as the most suitable method of maintaining the sea-walls between Blaney Rock and Woodbury's Point, the construction of steel sheet-pile cut-off walls where endangered by erosion, and the armoring of the entire sea-wall with a surface of reinforced concrete. The cost of the maintenance work would be borne by the Commonwealth of Massachusetts. For improving the beach, preventing erosion, and protecting the sea-walls and land areas between Woodbury's Point and the dune on the Nahant tombolo, a distance of 2,600 feet, he recommends raising the back shore to elevation 18.0 feet above mean low water with sand fill at an estimated cost of $366,000. For the prevention of breaching of the Nahant tombolo, and the loss of its beach, he recommends the construction of a free-standing stone mound, 6250 feet long, with a top elevation of 18.0 feet above mean low water, extending from the bathing beach to Little Nahant at an estimated cost of $98,000. The estimated cost of recommended improvements in which the United States would participate is $464,000 for new work, and $6,840 annually for maintenance.

The Division Engineer recommends that the Commonwealth of Massachusetts adopt a project for the recommended maintenance work between to all sections of the towns and to the principal traffic arteries of Metropolitan Boston. Free public parking is provided for the entire length of the beach by parking areas and roadside parking. All parts of the beach are open without charge to the public. The mainland area is developed as a very fine park with concrete promenades and lawns in back of the sea-wall and at a level partially below that of the highway. The tombolo area is developed as a picnic area with free fireplaces, playgrounds and bathing facilities. The bathhouse has accommodations for 3000 people, with a charge of twenty-five cents being made for its use. Daily attendance at the beach in season averages 10,000 people with maximum attendance being 15,000 people. The usability of the beach is not impaired by water pollution that would endanger the health of bathers.

surface, considerable care in placing the concrete due to the thin section and the reinforcing steel, and extensive hand finishing after the forms were removed if laitance and honeycoming occurs. The gunite would eliminate all difficulties arising from the shape of the wall and from the difficulties due to anchoring the facing material with dowels and reinforcement. Regardless of the method employed, prior to armoring the wall, all cracks in the existing wall will have to be raked out, all bad concrete cut out, all holes filled with new concrete properly anchored to the existing concrete, and all damaged steps and ramps rebuilt. It is considered that the armoring of the wall may be accomplished most satisfactorily and economically with reinforced concrete, provided every care is taken to insure proper mixing and placing to secure dense concrete, well anchored and bonded to the old wall. It may be expected that a more durable armor, having a greater period of usefulness and requiring less maintenance, may be obtained from air-entrained concrete placed by methods employing form-work than from concrete placed by the air-gun method, though the initial cost to such placement will be higher. Sections and details of this work are shown on Plate A-6.

50. Erosion of the beach at the base of the sea-wall has endangered sections of the wall. The extent and rate of this erosion are shown in Tables A and B in Paragraph 30. Several types of toe walls have been constructed at various locations to prevent the undermining of the main sea-wall. A study has been made of additional steps to be taken to ensure the stability of the wall. The beach elevation could be raised, but the beach would have to be built up with artificial fill since there is no littoral drift present for natural beach-building. The existing beach is a very hard-packed sand beach having a slope in the upper tidal range varying from 1 on 45 to 1 on 75 and a slope in the lower tidal ranges and offshore area varying from 1 on 100 to 1 on 150. These very flat sopes would necessitate very large quantities of fill for artificial beach building. It is not considered necessary that a beach be built at this

point for recreational purposes since the present beach is adequate for local residential use and large beach areas for transient bathers' patronage are provided south of Profile 12 and at Revere Beach. It is therefore considered that the construction of an artificial beach is not justified in this area.

51. Consideration was given to the placing of riprap at the base of the wall to prevent erosion, but since the high water line is at or near the wall it was not deemed advisable to further reduce the width of the beach by such construction.

52. The protection of the sea-wall thus resolves itself into the construction of toe walls to such depths as will prevent undermining. Many toe walls have been built to date, some of which have had to be replaced or rebuilt and some of which require repairing and rebuilding. These toe walls are of various designs and depths. This construction has resulted in a somewhat continuous, irregular shaped, toe wall which alters the basic shape and design of the curved wall. It is believed that it is undesirable to break up the smooth lines of the original structure. A study was made of the shapes, sizes and depths of these toe walls to determine if they could be removed and replaced by a continuous steel pile cut-off wall which would return the profile of wall to that of the original design. It was found that many of the present toe walls provide adequate protection for the main wall and are of such size that their removal would not be economically justified. New or additional protection is needed in certain areas. Where such protection is required, it is recommended that it be provided by means of a steel sheet-pile cut-off wall driven to elevation 0.0 at a point close to the present structure and, where exposed above beach elevations, encased with concrete to bond and blend with the recommended armor surface of the main wall. Where existing toe walls are adequate, it is recommended that all projecting corners be cut back and the wall built up as necessary to form a smooth curve continuous with the main sea-wall. Details of the treatment of toe walls are shown on Plate A-6.

VIII. ECONOMIC ANALYSIS

67. Basis of Analysis. - a. Estimates of first cost and annual benefits, have been made for all plans of improvement and protection recommended between Woodbury's Point and Little Nahant, Profiles 12 to 20. Cost estimates are given in Appendix III and summarized in Paragraph 68. Benefit estimates are given in Appendix IV and summarized in Paragraph 69.

b. A detailed economic analysis has not been prepared for the work recommended between Woodbury's Point and Blaney Rock, since the work comprises maintenance of existing structures and no Federal participation is involved. The maintenance of the existing walls is the responsibility of the owners and local authorities. The benefits to be derived from the project are the maintenance of the benefits which resulted from the initial wall construction, the reduction of future maintenance, the insurance of the future service and stability of the walls, and the protection of the public investment in the development of the reservation. With the exception of the reduction of maintenance costs, these benefits are such that assignment of monetary values is not readily accomplished. On the basis of past records, the average annual cost of repairing storm damage in this area is $12,000. Public property has an estimated valuation of $1,512,000, comprising land valued at $120,000, sea-walls at $1,200,000 and roads at $192,000. Private property fronting the shore drive has an assessed value of $1,133,000 and marginal property within 1000 feet of the drive, but exclusive of frontal property, has an assessed valuation of

$5,741,000. The total annual tax return on the property is $301,000. The annual costs of repairing storm damage, and the value of public property and private property to be maintained through the repairs of the sea-wall are believed to be sufficient to justify the accomplishment of recommended repairs by local interests.

68. Estimates of First Costs. - The first cost of the plans of protection and improvement discussed in Paragraphs 54 to 66, inclusive, are estimated to be as follows:

a.	Improvement of Beach, Profiles 12-16	$366,000.
b.	Protection of Nahant Beach, Profiles 16-20	98,000.

Detail estimates of above costs are presented in Appendix III.

69. Estimates of Benefits. (See Appendix IV) a. General. - The benefits discussed herein are the benefits to be derived from the recommended plans of improvement for that part of Lynn-Nahant Beach lying between Woodbury's Point and Little Nahant. The benefits result from direct and indirect damages prevented, increased recreational facilities, increased property values, and the prevention of isolation of an entire town, including the isolation of major harbor defense posts.

b. Average Annual Direct Damages Prevented. - Estimated average annual expenditures to repair direct damages over the period of record have been:

Federal	$ 0
Non-Federal Public	14,050
Private	0
Total	$ 14,050

Nahant, to prevent flanking by flood water. The cooperating agency should be required to obtain such land, rights-of-way, and easements, as the final construction plans indicate to be necessary.

d. Benefits and Interests. - The amount of the interest of one agency in a project is the percentage of that agency's benefits to the total benefits to accrue from the project. On the basis of benefits evaluated in Paragraph 69, the percent of benefits derived by each agency is as follows:

Agency	Annual Benefits	Percent of Interest
Federal	$ 0	0
Non-Federal Public	37,300	89
Private	4,470	11
	$41,770	100

71. Allocation of Costs. - The policy for the allocation of costs is expressed in Public Law 727, 79th Congress, 2nd Session. The Federal share of the cost is determined as a percentage, not to exceed 33-1/3 percent, of the total cost of construction of works for the improvement and protection of shores owned by States, municipalities, or other political subdivisions, excluding costs of necessary lands, easements and rights-of-way. The federal share of the cost of a project thus becomes the percentage of the total interest represented by the Federal interest plus a percentage of the cost of the non-Federal public interest as allowed under the law. The non-Federal share of the cost is represented by the non-Federal interest in the total interest less the Federal contribution allowed under the law.

72. Federal interest is shown in Paragraph 70 to be zero. Federal participation in the proposed plan of improvement, as determined in Paragraph 75, is one-third of the construction cost. The total Federal share

prising buildings, roads, and Lynn Harbor shore protection, valued at $405,000. The proposed works will maintain the public investment. The tombolo is the only connection for the entire town of Nahant with the mainland. The proposed project will prevent inundation of the tombolo by storm waters from Nahant Bay and prevent eventual breaching of the tombolo, both of which conditions isolates the entire town. Isolation of the town involves at all times economic losses to both business and private citizens, and under severe conditions, many involve loss of human life and public welfare. Isolation of the town also isolates principal coast defense positions and thereby involves national security. The proposed project will improve recreational facilities along part of the beach and provide for future improvement of facilities on the balance of the beach. It is concluded that the evaluated and unevaluated public benefits derived from the proposed project are sufficient to justify its construction. The total annual benefits to accrue from the project, evaluated and non-evaluated, are deemed to have a much greater ratio to the annual estimated carrying charges for the work than the evaluated ratio of 1.5 to 1.

75. The proposed plan of improvement will protect public property, and will further provide for the encouragement of the healthful recreation of the people. The shore to be protected is owned by the Metropolitan District Commission of the Commonwealth of Massachusetts. The public interest in the protection and improvement of the beach between Woodbury's Point, Lynn, and Little Nahant, has been found to be substantial. Benefits to the Federal government to be derived from the prevention of shoaling in the Lynn Harbor channel and from national defense are of such intangible nature, and are so greatly exceeded by other local public benefits that they are not considered sufficient to justify special contribution of funds for the protection of the Nahant tombolo. The protection and improvement of this publicly-owned beach and property, and the degree of public interest in such work are considered sufficient to warrant the full one-third Federal contribution to the first cost of the plan of improvement as authorized by the general provisions of Public Law 727.

caused by previous toe wall construction are to be cut off, so that the wall will present a smooth curved face. The sea-wall projections are not strong enough to withstand the energy released by breaking up the waves. The most satisfactory and economical method of armoring the sea-wall has been determined to be the application of a reinforced concrete surface over the entire wall. Where erosion has endangered the stability of the wall, steel sheet-pile cut-off walls are to be driven to the elevation of mean low water. Steel sheet-piling was selected for cut-off walls because it may be driven to depths at which there is no future danger of the wall being undermined. The analysis of the rates of erosion at the base of the sea-wall indicates that after the steel sheet-pile cut-off walls are driven, and at the present rate of erosion, it will require 39 years before the beach elevation will reach the base of the highest of the existing concrete toe walls. In view of the slow rate of erosion at the base of the wall, and the degree of protection afforded the cliff by the wall, it is to be expected that the plan of armoring and stabilizing the sea-wall will result in its continued successful operation for a substantial period of time. However, local authorities should frequently check the stability of the wall in relation to superimposed loads and beach elevations. If in the future, sections of the wall are found at any time to be endangered, heavy riprap may be required in front of the endangered sections at the sacrifice of beach areas.

83. The method to be employed for the protection of the walls south of Woodbury's Point is subject to the development of the plan of improvement for the bathing beach area. The situation of the bathing beach is one in which the backshore is too stony to provide a satisfactory

flexibility makes it adaptable to foundation conditions and if subsequent settlement or partial breaching should occur, it can be readily restored to grade.

87. The proposed plan of armoring the sea-walls between Blaney Rock and Woodbury's Point (Profile 1 to ~~16~~ 12 Area) is found to be maintenance, required to repair and stabilize the wall to insure its continued successful protection of the coast. The provisions of Public Law 727, which law provides for Federal participation in the cost of construction of shore protective works, are very explicit in stating that the Federal Government will not participate in the maintenance of protective structures. The special provision of Public Law 727 provides for Federal participation in the repair of existing walls where the walls protect "a public highway considered by the Chief of Engineers sufficiently important to justify protection". Lynn Shore Drive adjacent to the sea-wall, is a localized parkway which cannot be deemed important to the welfare of the general public. Numerous side streets are available to connect to other areas of Lynn and Swampscott. A principal State highway route parallels the drive about 0.2 miles landward. The loss of the shore drive would not endanger the general public nor disrupt free flow of traffic in the community. Traffic disruption would be limited to those having business at residences on the drive. Federal participation in the plan of maintenance is therefore not in accordance with the policy set forth under existing law. The accomplishment of the recommended work would thus become the responsibility of local interests.

public benefits are considered to be sufficient to warrant the maximum one-third participation by the United States in the first cost of the proposed new construction, as permitted by Public Law No. 727, 79th Congress, 2nd Session.

92. Recommendations. - It is recommended that the Commonwealth of Massachusetts adopt a project for the protection and improvement of Lynn-Nahant Beach to the extent of:

a. Constructing steel sheet-pile cut-off walls between Blaney Rock and Woodbury's Point at those places where toe walls do not extend below elevation 6.0 feet above mean low water, and providing an armor of reinforced concrete on the existing concrete wall in the same section, the entire cost of which is to be borne by the local agencies.

b. Improving the beach between Woodbury's Point and the dune on Nahant tombolo, a distance of about 2,600 feet, by placing approximately 172,000 cubic yards of sand thereon, to provide a backshore elevation of 18.0 feet above mean low water, and constructing a stone mound having a top elevation of 18.0 feet above mean low water along the tombolo from the improved beach to Little Nahant, a distance of 6,250 feet, all at an estimated initial cost of $464,000 and $6,840 annually for maintenance.

93. It is recommended that the United States adopt a project for the protection and improvement of the shore between Woodbury's Point and Little Nahant by authorizing participation through the contribution of Federal funds in an amount equal to one-third of the first cost of construction of the project. The project consists of the work described in Subparagraph 92-b and its cost to the United

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L

APPENDIX III

COST ESTIMATES FOR LYNN-NAHANT BEACH

(Cost of Work Recommended Between Profiles 12 and 20)

I. ESTIMATED FIRST COSTS

1. Improvement of Beach, Profiles 12-16 Area. - Placement of sand fill.

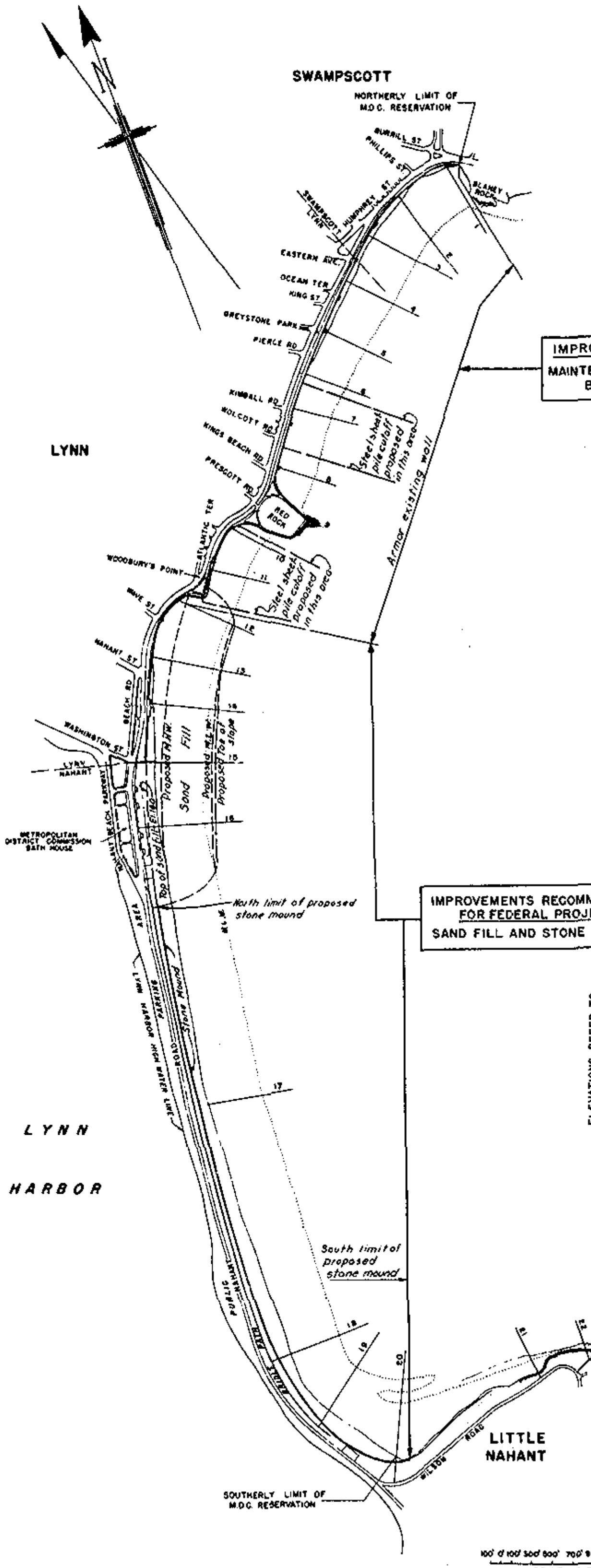
Sand fill, 172,000 cubic yards @ $1.85	$318,200
Engineering and Contingencies	47,800
	$366,000

2. Protection of Nahant Beach. - Construction of 6250 linear feet of stone mound.

a.	Earthwork, excavation and backfill, 6000 cubic yards @ $.50	$ 3,000
b.	Stone core, 12,220 Tons @ $3.75	45,825
c.	Stone shell, 6630 Tons @ $4.50	29,835
d.	Stone steps, 230 Tons @ $20.00	4,600
e.	Rehandle existing riprap, 2400 Tons @ $1.00	2,400
		$ 85,660
	Engineering and Contingencies	12,340
		$ 98,000

WAR DEPARTMENT

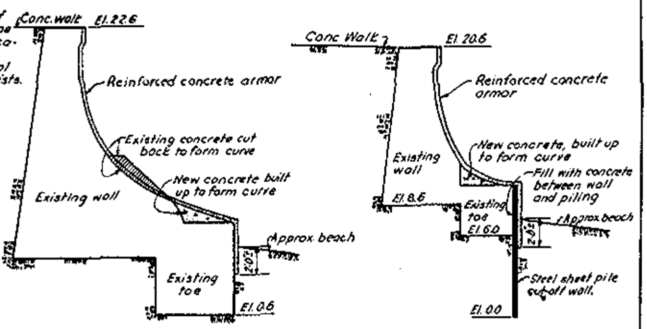
CORPS OF ENGINEERS U. S. ARMY



NOTE

Existing toe does not extend entire length of wall and varies in shape and size at various locations.

Sections show typical conditions where toe exists.


Conc. walk
El. 22.6
Reinforced concrete armor
Existing concrete cut back to form curve
New concrete built up to form curve
Existing wall
Approx. beach
2.0'±
Existing toe
El. 0.6
Conc Walk
El. 20.6
Reinforced concrete armor
New concrete, built up to form curve
Existing wall
Fill with concrete between wall and piling
El. 8.6
Existing toe
El. 6.0
Approx. beach
2.0'±
Steel sheet pile cut-off wall.
El. 0.0

SECTION NEAR PROFILE 8

TYPICAL TREATMENT WHERE CUTOFF WALL IS NOT REQUIRED

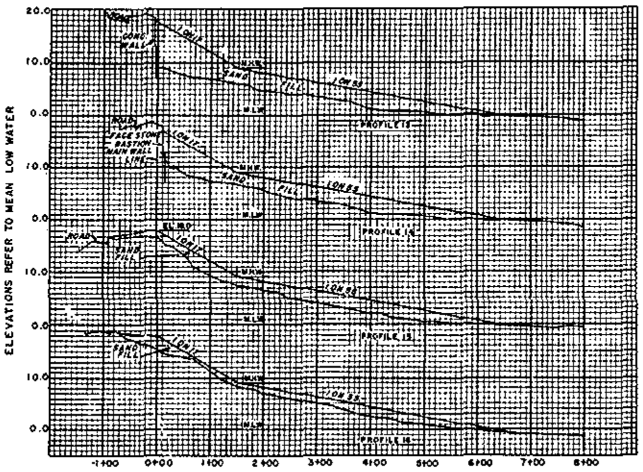
SECTION AT PROFILE 7

TYPICAL TREATMENT WHERE CUTOFF WALL IS REQUIRED

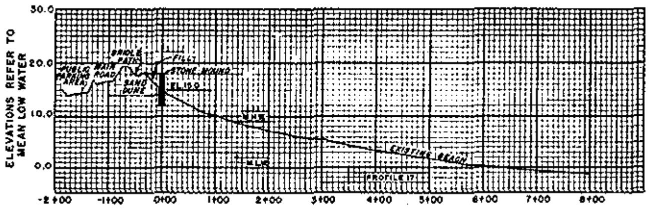
DETAILS OF ARMOR AND STEEL SHEET-PILE PROTECTION

FOR EXISTING CONCRETE WALL

SCALE $\frac{3}{4}$" = 1'-0"

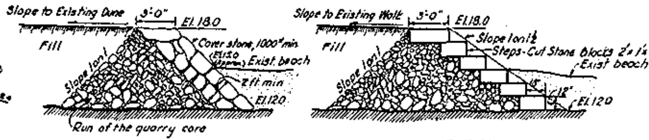


TYPICAL SECTIONS OF SAND FILL



LOCATION OF STONE MOUND

TYPICAL SECTION AT PROFILE 17



TYPICAL SECTION

STEP SECTION

DETAILS OF STONE MOUND

SCALE $\frac{1}{4}$" = 1'-0"

4' 0 4' 8'

NOTE

Steps required at 25 locations to provide access to fireplaces and tables at base of sand dunes.

NOTES

All elevations refer to Mean Low Water.

Beach profiles from survey by Corps of Engineers, Oct-Dec. 1945 and May 1946.

Nahant Road and Public Parking Area was reconstructed in 1947, and relocated so that Public Parking Area is adjacent to sand dune.

To Accompany Report Dated: June 1, 1949

R

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

DRAWN BY P.D.M.
TRACED BY P.D.M.
CHECKED BY
SUBMITTED BY
APPROVED
CHIEF, E.&N. OPERATIONS DIV.

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY

PLANS OF PROTECTION

LYNN-NAHANT BEACH

MASSACHUSETTS

APPROVED James H. Stratton
COL., DIVISION ENGINEER
DATE MAY 31, 1949

SCALE AS SHOWN

DRAWING NUMBER
52 F-15-2

PLATE NO. A-6

LYNN-NAHANT BEACH

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*Apply also to Part B - Revere Beach

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NOT FOR PUBLIC RELEASE

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF METROPOLITAN DISTRICT COMMISSION BEACHES, BOSTON, MASSACHUSETTS

INTRODUCTORY

The cooperative study of Metropolitan District Commission Beaches in Metropolitan Boston, Massachusetts, comprises studies of five beaches, one of which (Winthrop Beach) has previously been reported on to Congress. These beaches are essentially independent of each other, in so far as the scope of the study is concerned. The cooperating agency stated its objective in the prosecution of the study to be the determination of the best method of preventing further erosion, stabilizing, and improving the beaches, and protecting the sea-walls. Report on the remaining beaches is made in four parts, as follows:

A. Lynn-Nahant Beach
B. Revere Beach
C. Quincy Shore Beach
D. Nantasket Beach

SYLLABUS - LYNN-NAHANT BEACH

The Division Engineer finds that the existing sea-walls extending from Blaney Rock to the bathing beach, although adequate for the protection of the coastal cliff are now endangered by the eroding beach and are in need of repair, and that the bathing beach south of the sea-walls is generally unsatisfactory for recreational purposes, and is too low to prevent storm waves attacking adjacent land areas. He also finds that there is danger of the Nahant tombolo, which extends from the bathing beach to Little Nahant, being breached by storm waves.

The Division Engineer recommends as the most suitable method of maintaining the sea-walls between Blaney Rock and Woodbury's Point, the construction of steel sheet pile cut-off walls where endangered by erosion, and the armoring of the entire sea-wall with a surface of reinforced gunite at an estimated cost of $138,000. The cost of the maintenance work would be borne by the Commonwealth of Massachusetts. For improving the beach, preventing erosion, and protecting the sea-walls and land areas between Woodbury's Point, and the dune on the Nahant tombolo, a distance of 2,600 feet, he recommends raising the back shore to elevation 18.0 feet above mean low water with sand fill at an estimated cost of $366,000. For the prevention of breaching of the Nahant tombolo, and the loss of its beach, he recommends the construction of a free-standing stone mound, 6250 feet long, with a top elevation of 18.0 feet above mean low water, extending from the bathing beach to Little Nahant at an estimated cost of $98,000. The estimated cost of recommended improvements in which the United States would participate is $464,000 for new work, and $6,840 annually for maintenance.

The Division Engineer recommends that the Commonwealth of Massachusetts adopt a project for the recommended maintenance work between

Blaney Rock and Little Nahant, and that the United States participate in that part of the project between Woodbury's Point and Little Nahant by contributing funds in an amount equal to one-third of the cost of the construction of new work, estimated to be $154,670, subject to the conditions specified in the report.

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASS.

June 1, 1949

SUBJECT: Beach Erosion Control Report on Cooperative Study of Metropolitan District Commission Beaches, Boston, Massachusetts; Part A - Lynn-Nahant Beach.

TO: The Chief of Engineers
Department of the Army
Washington 25, D. C.

I. GENERAL

1. Authority. - A formal application from the Metropolitan District Commission of the Commonwealth of Massachusetts, dated August 9, 1945, for a cooperative study of beach problems within the Metropolitan District in the vicinity of Boston, Massachusetts, including Lynn-Nahant Beach, Revere Beach, Winthrop Beach, Quincy Shore Beach and Nantasket Beach, and providing for prosecution jointly by the Metropolitan District Commission and the United States was approved by the Chief of Engineers, United States Army, October 2, 1945, in accordance with the authority conferred by the provisions of Section 2 of the River and Harbor Act approved July 3, 1930 and Public Law 166, 79th Congress, approved July 31, 1945.

2. At the request of the Metropolitan District Commission, the study of Winthrop Beach was given priority over the study of other beaches to allow a separate report to be made on Winthrop prior to completion of the entire study. A report on "Beach Erosion Control Study, Winthrop Beach, Mass." was made by the Beach Erosion Board and submitted to Congress December 9, 1948, and is published in House Document No. 764, 80th Congress, 2nd Session.

3. Purpose. - The purpose of the investigation of the general study of Metropolitan District Beaches is to determine the best method of preventing further erosion, stabilizing and improving beaches, and protecting the sea-walls.

4. Prosecution of the Study. - The Commonwealth of Massachusetts, through the Metropolitan District Commission, contributed one-half the cost of the study. The field work and collection of basic data for the study were carried out by the District Engineer, Boston, Massachusetts, with the exception of economic data, which were collected by the cooperating agency. A geological study of the area except the mainland section of the Lynn-Nahant Beach was prepared by the United States Department of the Interior, Geological Survey, under a cooperative geological project of the Massachusetts Department of Public Works. The report on Winthrop Beach was prepared by the Beach Erosion Board. The report on other beaches included in the study has been prepared by the Division Engineer, New England Division.

5. Preparation of Reports. - The five beaches comprising the study, in so far as their physical location and the scope of the study are concerned, are independent shore units which may properly be treated as separate beaches. A separate report has been prepared on Winthrop Beach. The report on the remaining beaches has been divided into four parts, as follows:

Part A - Lynn-Nahant Beach
Part B - Revere Beach
Part C - Quincy Shore Beach
Part D - Nantasket Beach

Each of the four parts is issued as a complete report for the subject beach, and contain general paragraphs numbered 1 to 5, inclusive, and Plates 1 and 2, which are common to all four parts. Plates A-2, A-3, A-4 and A-5 of Part A also pertain to Part B and are therefore also inserted in that part.

II. DESCRIPTION

6. Location. - The beach designated in this report as "Lynn-Nahant Beach" is one continuous beach comprising King's Beach Reservation in the Town of Swampscott, Lynn Shore Reservation in the City of Lynn, and Nahant Beach Parkway in the Town of Nahant, all in Essex County, Massachusetts. The beach is 7-1/2 miles north of the main entrance channel to Boston Harbor and 9 miles northeast of the City of Boston. (See Plate 1, U. S. Coast and Geodetic Survey Chart No. 1207 and U. S. Geological Survey, Boston Bay Quadrangle).

7. General Description. - Lynn-Nahant Beach comprises a bayhead beach and tombolo forming the head of Nahant Bay, and extends a distance of 2-3/4 miles between two headlands, Blaney Rock on the north and Little Nahant on the south. The portion of the beach in Swampscott, called King's Beach Reservation, and in Lynn, called Lynn Shore Reservation, fronts a moderately high coastal cliff. The coast is highly developed, being a better than average year-round residential area, with many large houses fronting Lynn Shore. The area also contains high type apartment hotels. The residential area extends inland for over a half mile to the center of Lynn.

8. The Metropolitan District Commission Reservations in Lynn and Swampscott consist of a narrow public beach, a sea-wall, a wide promenade, a grass plot of varying width along Lynn Shore and a wide boulevard. The beach is generally hard-packed sand which extends to the base of the wall. At Red Rock, in the center of Lynn Shore Reservation, there is a large ledge outcrop. South of Red Rock the beach material becomes coarser and contains some stone and a few boulders.

9. The portion of the beach in Nahant, called Nahant Beach Parkway, is the seaward face of a tombolo connecting the former island of

Little Nahant to the mainland. The tombolo in the study area averages about 350 feet in width and separates Lynn Harbor from the sea. At the land base (north end) of the tombolo, there are several refreshment stands, a state-operated public bathhouse, and several playground areas. The entire tombolo is a part of the Nahant Beach Parkway Reservation under control of the Metropolitan District Commission, except that the paved road, Nahant Road, adjacent to Lynn Harbor, is owned by the Town of Nahant. Along the center of the tombolo there is a continuous bituminous paved, free public parking area. On the seaward side of the parking area is a low sand dune, the crest of which is traversed by a paved bridle path. There are 23 free picnic fireplaces each provided with tables along the length of the tombolo. The backshore of the seaward beach is medium hard-packed sand and the foreshore is hard-packed sand with considerable small stone in the north central area.

10. The Lynn-Nahant Beach is the result of erosion of mainland headlands and of the former island of Little Nahant, and deposition of wave transported materials from other sources, under which effect the island was tied to the mainland. This process did not leave any shoals or bars in front of the beach. The offshore area immediately adjacent to the beach is relatively shallow, with the 18-foot contour being about 4500 feet from the shoreline. Beyond this point, the ocean bottom drops rapidly to a depth of 60 feet about 10,000 feet from the shoreline.

11. Lynn-Nahant Beach is paralleled for its entire length by excellent public highways which are separated from the beach proper by public walks and promenades. The only road to Nahant traverses the tombolo. The drive along the Lynn and Swampscott sections is part of a state highway route. The entire area is connected by excellent roads

to all sections of the towns and to the principal traffic arteries of Metropolitan Boston. Free public parking is provided for the entire length of the beach by parking areas and roadside parking. All parts of the beach are open without charge to the public. The mainland area is developed as a very fine park with concrete promenades and lawns in back of the seawall and at a level partially below that of the highway. The tombolo area is developed as a picnic area with free fireplaces, playgrounds and bathing facilities. The bathhouse has accommodations for 3000 people, with a charge of twenty-five cents being made for its use. Daily attendance at the beach in season averages 10,000 people with maximum attendance being 15,000 people.

III. GEOLOGY

12. Classification of Beach. - The Lynn-Nahant beach comprises a narrow bayhead beach fronting the mainland cliff and a slender tombolo, about 350 feet wide, which joins the former island of Little Nahant with the mainland. The crest of the tombolo is 15 to 20 feet above mean low water, and sand dunes, a few feet high, rise in places above mean high water.

13. Bed Rock. - Bed rock crops out at Little Nahant, at Red Rock and at Blaney Rock. Rocky cliffs extend above the high water mark to quite high elevations at many places on Little Nahant. While the ledge outcrops at Red Rock and Blaney Rock reach lower elevations. If these cliffs had been formed by wave action during the present stand of the sea, they would have supplied considerable material to the adjacent beaches. The almost total absence of wave-cut platforms associated with them proves that they are not marine cliffs. They were probably formed by glacial plucking, and the sea later came to rest against them. Little material derived directly from bed rock is being added to Lynn-Nahant Beach at the present time and it seems likely that it has not been an important source in the past.

14. Surficial Deposits. - a. Till. - Till thinly veneers bed rock at Little Nahant and generally in the area north of the mainland base of the Nahant tombolo. The till contains clay, silt and sand, as well as larger fragments. The mainland beach and tombolo beach were built in part from material derived through the erosion of the till. The southern and northern ends of the tombolo are composed in part of coarse gravels containing many kinds of rocks which were derived from the erosion of the nearby till. The till in these areas is now furnishing little material to the beach because most of the till that could be

reached by wave action has been removed and sea walls protect most of the rest of it. Deposits of till offshore may have supplied material to the beach in the past. Although the till contains clay, silt and sand, as well as larger fragments, none of the clay and little of the silt were used in the building of the Nahant tombolo.

b. Outwash Sands and Gravels. - No deposits of outwash sands and gravels are known to be supplying material to the beach at the present time. It is possible that outwash material offshore from Lynn-Nahant Beach may have supplied material in the past.

c. Clay. - Borings indicate that blue clay underlies much of the beach. The clay rests on till, outwash and bed rock, and was deposited at a time when sea level was approximately 30 feet higher than at present. It contains a small fraction of material larger than silt sizes, and some of this coarser material, was probably used in the construction of the Lynn-Nahant Beach. As the surface of the clay in the area is usually below the low tide mark, it is not now an important source of beach material.

d. Fluvial Silt, Sand and Gravel. - Following the deposition of the clay, sea level dropped to a point scores of feet below its present stand, so that the shore line was several miles to the east of its present position. During this period, silt, sand and gravel were deposited on the clay by streams that flowed across it. Some of this material was also used in the construction of the beach, although it was probably not an important source.

e. Alluvial Marshland Deposit. - A deposit of marshland silt, muck and peat occurred in a small area immediately south of Blaney Rock. This area was separated from the ocean by a narrow beach. This material was probably not important in building the beach and cannot furnish additional beach material as it is fully protected by a seawall.

f. Summary. - In summary it may be said that bed rock has supplied little or no material directly to Lynn-Nahant Beach. Till, blue clay, fluvial sand and gravel, and probably outwash were sources of beach material, but their relative importance cannot be judged. When the width of the Nahant tombolo is compared with the widths of Winthrop and Nantasket Beaches it is to be seen that the source of materials for the Nahant tombolo was not as plentiful as for the other tombolos.

15. Geologic History. - a. The till and outwash are the oldest surficial deposits in the area. They rest on bed rock and are much younger than the bed rock. Shortly after the deposition of the till and outwash, sea level stood approximately 30 feet higher than at present. During this period Little Nahant was an island and the blue clay was deposited in the ocean by glacial-fed streams. After a short interval at this relatively high stand, the sea level dropped slowly to a position scores of feet lower than the present position. During this low stand of the sea, rivers flowed across the clay and probably other deposits, and in places silt, sand, and gravel were deposited. At this time, Little Nahant was connected with the mainland by a coastal plain underlain by the blue clay. Beaches were formed at this low level by material derived from various sources.

b. After a period of unknown length, the sea rose from this low level and the beaches moved landward with the shoreline. When the sea finally reached the eastern end of Little Nahant, a seaside beach extended from this point to the mainland.

c. Continued rising of sea level caused the shoreline and seaside beach to advance westward so that Little Nahant again became an island. A spit was probably formed shortly after the shoreline passed westward beyond the eastern end of Little Nahant. This spit grew to the northwestward from a point near the eastern end of Little Nahant and the material in it was derived mainly from till. At the same time a spit was formed near the southern end of the mainland beach, with the spit subsequently extending itself southward.

d. It is unlikely that the Nahant tombolo resulted entirely from the growth of these spits. Most of the material in the tombolo was probably deposited by wave action from various offshore sources.

e. It is not known how early Little Nahant was joined to the mainland by a continuous beach. Near Little Nahant the beach has retrograded slowly westward and may now be more than 1000 feet west of the initial position of the spit. The material in the dunes near the crest of the tombolo was transported from the beach face by onshore winds.

IV. FACTORS AFFECTING SHORE PROCESSES

16. Composition of Beach. (Figures A-1 to A-3). - a. The shore of the two headlands at Blaney Rock and Little Nahant is rocky and boulder strewn where the ledge does not outcrop about the beach. With the exception of the Red Rock area, which is of outcropping ledge, the intervening beach consists of hard-packed sand with varying deposits of stone and gravel on the backshore areas. The amount of stone and gravel varies with the location and the periods of varying wind and wave conditions. Detailed descriptions of the beach at the various profiles are given in Appendix II.

b. Prior to the construction of the sea-walls along Lynn Beach and King's Beach in 1904 and 1907, borings were taken to determine subsurface conditions along the line of the walls. Additional borings were taken in 1929 for the 60-foot extension of the northerly end of the King's Beach sea-wall. These borings indicate that subsurface materials are generally clay, sand,and gravel of varying amounts and types. The strata of the several materials vary in position and relation to each other, indicating deposits occur as pockets or lenses. The depth to which borings were taken varied with their location along the beach.

17. Borings Along Sea-Walls. - a. The borings for the King's Beach sea-wall extension taken prior to its construction, indicated a rapid change in material in the area. At the north end of the extension there was 18 feet of gravel fill overlaying 10 feet of fine sand and clay,and hard-packed sand and gravel. Ledge was found about 1.5 feet below mean low water. At the south end of the extension there was 18 feet of gravel fill overlaying 10 feet of hard clay and 13 feet of fine sand and clay. Ledge was found 13 feet below mean low water.

b. Near Profile 1 there was 1 to 8 feet of sand, overlaying yellow clay. The borings extended to a depth of 2.5 feet below mean low water. Near Profile 2, 15 to 17 feet of material varying from beach sand and gravel through fine sand mixed with seaweed to coarse sand, overlaid clay which was generally 6 feet below mean low water. The borings extended to a depth of 7.5 feet below mean low water.

c. Near Profile 3, borings were taken to a depth of 27 to 41 feet below mean low water. Clay occurred 24 to 37 feet below mean low water and was overlaid with materials varying from sand, gravel and stones, through sand and dock mud, to sand and gravel. Between Profiles 4 and 6, borings were taken to depths varying to 38 feet below mean low water. Clay was found at depths from 0 to 10 feet below mean low water and was overlaid by beach stones, and gravel and sand. Between Profiles 7 and 8, the borings were taken to depths of 25 to 40 feet at which elevations ledge was found. The ledge was overlaid with clay and mixtures of sand and clay which extended up to mean low water. Above mean low water there were deposits of beach stones.

d. Borings near Profiles 10 and 11 generally extended to about mean low water. These borings indicated 3 feet of beach sand overlaying strata of yellow and blue clay, intermingled with strata of sand and gravel. The lowest stratum was not always found to be clay. Two borings near the base of the Red Rock area encountered ledge 2 to 3 feet above mean low water. Borings taken in the vicinity of Profile 12 to a depth of 0 to 3 feet below mean low water indicated 2 to 4 feet of beach sand above strata of blue and yellow clay which overlaid strata of sand and gravel. Borings near Profile 13 extended to 1 to 3 feet above mean low water and indicated 2 to 3 feet of beach sand overlaying strata of blue and yellow clay.

LYNN-NAHANT BEACH

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the mean. At Boston Harbor the predicted spring tides range up to 12.0 feet; actual heights of extreme tides having been recorded up to 15.0 feet above mean low water.

21. Storms and Their Effects. - The paths of all hurricanes (defined as those with a central pressure of 29.0 inches or lower and winds near the center of more than 60 miles per hour in some points in the path) which have struck within a 150-mile radius of Lynn-Nahant Beach between the years 1874 and 1944 have been extracted from the book, "Hurricanes", by Ivan R. Tannehill, and various other sources and are shown on Plate 2. Between 1874 and 1945, a period of 71 years, 32 tropical storms of hurricane intensity have passed within a 150-mile radius of Lynn-Nahant Beach.

22. A summary of the record of winds of gale force or greater compiled from records of the U. S. Weather Bureau at Boston, Massachusetts, covering the 75-year period 1870 to 1945, inclusive, is given in the following table:

DIRECTION OF GALES

1870-1945 (incl.)

Direction	Number of Gales	Per Cent of Total Gales
North	3	2
Northeast	80	50
East	9	6
Southeast	14	9
South	12	7
Southwest	15	9
West	13	8
Northwest	14	9
	160	100

23. The following table based upon the gale record summarized above, indicates the number of days that gales from various directions may be expected during a 100-year period.

GALE FREQUENCY BY DIRECTION

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	TOTAL
Number of days observed 1870 to Jan. 1946	4	131	9	15	12	20	16	18	225
Frequency in days per 100 years	5	175	12	20	16	27	21	24	300

During a 100-year period 175 gales, comprising 58 per cent of all gales, may be expected from the northeast. Only 32 gales (11 per cent of all gales) are to be expected from both the east and southeast.

24. Storm damage along Lynn-Nahant Beach results from the action of wind driven waves and their induced currents,and its severity is directly dependent upon the velocity and direction of the wind and the tidal stage during the storms. The configuration of the coast in the Lynn-Nahant area is such that the beach is acted upon only by waves originating from north, east and south quadrants. While the beach is generally exposed directly to the east and southeast, the refraction of waves by Philip's Point and the Nahant tombolo result in action on the beach by waves originating from the north and northeast. Winds from the northeast quadrant have great preponderance, in regard to both duration and velocity, over the other winds producing waves which can act upon the beach. Storms from the northeast have a much greater frequency and duration than storms from other quadrants. Northeast storms,therefore, have the greatest effect upon the Lynn-Nahant Beach.

25. The Lynn-Nahant Beach comprises two distinct sections; the developed mainland area of Lynn Shore and King's Beach, and the undeveloped tombolo area of Nahant. The mainland area is protected by a continuous sea-wall of mass concrete except for a short section of rubble masonry at its southern end. The tombolo area is protected by stone riprap extending from a point near its land base to about its

midpoint. The Lynn-Nahant Beach is subject to continuous moderate surf action which has the greatest effect upon the mainland coast since the sea-walls in this area are generally located at, or seaward of, the mean high water line. Consequently the intensification of wave action under storm conditions results in greater damage along the mainland beach than along the tombolo. Damage to the concrete sea-walls along the mainland consists of spalling and disintegration of their faces; breaking off of sections of coping, and toes; breaking up of concrete steps; destruction of railings; and undermining of walls. Damage to the rubble masonry walls consists of dislodgment of stones, and undermining. Damage in back of the walls have been of a minor nature, consisting of washouts in the lawns; and breaking-up of concrete walks and concrete park benches.

26. The tombolo area is not generally subject to severe storm damage, though the road to Nahant is flooded at times of extreme high water. Some wave-wash passes over dunes from the open sea but some of the flood waters come from Lynn Harbor which is adjacent to the road. The flooding due to high waters in Lynn Harbor has been partially eliminated by the reconstruction of harbor line sea-walls. The beach and dune have been considered stable and a bridle path was constructed along the top of the dune and heavy masonry fireplaces were constructed at its base for the entire length of the beach. These structures remained undamaged until November 1945 when the unprotected seaward face of the dune was severely eroded and bridle path partially destroyed. The shore protection along the harbor side has, in the past, suffered considerable and recurring damage.

27. Storm damage as reported in the press in recent years is as follows:

a. January 26-29, 1933. - Northeast storm. Minor damage to sea-walls. Road to Nahant buried under two feet of sand. The granite wall along the Lynn Harbor side of tombolo was damaged with a few new washouts. Nahant was made an island during the storm with tides up to 13.5 feet high.

b. November 17-18, 1935. - Northeast storm. Surf broke over Lynn Shore Drive.

c. September 22, 1938. - Southerly storm (New England Hurricane). Boats were wrecked along the beach. Travel was stopped across the tombolo to Nahant.

d. November 5, 1939. - Northeast storm. Waves broke over sea-wall.

e. February 22, 1940. - Northeast storm. Heavy spray from waves. At Shag Rocks, Nahant; spray was observed 75 feet high.

f. April 20-22, 1940. - Northeast storm. Stone and sand washed over road to Nahant, with road closed at high water. Surf broke over the sea-wall, tearing up 150 concrete and wood settees, undermining the sidewalk, and flooding lawns.

g. January 12, 1941. - Offshore gales caused heavy wave action, resulting in spectacular surf but resulting in little damage.

28. Representatives of the District Engineer, Boston, Massachusetts inspected the area following the storms of November 28-30, 1945 and December 19, 1945. The following reports were based upon these field inspectors.

a. - November 28-30, 1945. - Northeast storm. - (1) This storm was 53 hours in duration, in which the wind attained a maximum velocity of 68 m.p.h. The storm came at a neap range of tides in which predicted tides at Boston, Mass., were from 8.4 to 8.9 feet. The recorded tides in Boston were 9.1 to 12.5 feet, which approached and exceeded maximum normal tides. This storm caused extensive damage all along the coast.

(2) Along Lynn Shore Drive, the damage experienced was light and consisted generally of damage to lawns and to the guard rail on the sea-wall. There was accretion at the north end of the beach and slight erosion at the south end. Twenty-five feet of the granite block wall adjacent to the newly constructed ramp near the bathhouse was partially broken down and the new concrete sidewalk in back of the wall was broken up.

(3) Along the Nahant Parkway Beach considerable erosion was caused to the low sand dune. This dune had been stable for years, but was almost breached during the storm. The paved walk along the top was broken up in numerous places and a 30-foot boat was tossed to the top of the dune. The 23 masonry fireplaces at the toe of the dune were generally undamaged but the dune was cut back 15 to 20 feet from their bases. The beach elevation around the fireplaces was lowered from 2 to 3 feet. The road was flooded and buried under sand and stone. Washouts, up to 15 feet deep, occurred along the Lynn Harbor side of the tombolo.

b. December 19, 1945. - Northeast storm. Additional damage was done to the wall and sidewalks damaged near the Lynn Bathhouse on November 28-30, 1945.

V. CHANGES IN BEACH AND OFFSHORE AREAS

29. Changes in Shore Lines. - a. General. - Changes which have been effected on the beach are indicated by the comparison of the mean high and low water lines shown on Plate A-2. The plot of these shore lines was developed from original U. S. Coast and Geodetic Surveys for the years 1849, 1847-50, 1893-94, 1919 and 1944, and from the survey made for this study in 1945-46, by the District Engineer. The 1944 survey was made by aerial photographic methods, and its plot is to be considered indicative of general trends. For the purposes of study, the shore line may be divided into four sections, as follows:

1. Profiles 1 - 9, the shore line between Blaney Rock and Red Rock.
2. Profiles 9 - 15, the mainland shore south of Red Rock.
3. Profiles 15 - 20, the tombolo.
4. Profiles 20 - 24, the shore of Little Nahant.

b. Changes Between Profiles 1 and 9. - The plot of the mean high water line indicates a stable shore. There has been minor erosion and accretion during the period of record, with the 1945-46 mean high water line showing accretion predominating between profiles 2 and 6. Since the entire shore was stabilized by the construction of a sea-wall in 1909, the 1945-46 mean high water line cannot be directly compared to the earlier surveys shown. Comparison of beach elevations taken along the base of the wall prior to construction and similar beach elevations taken in 1945-46, indicate erosion has generally been affected along the base of the wall. The only available plot of the mean low water line is that of the 1945-46 survey.

c. Changes Between Profiles 9 and 15. - The plot of the mean high water line indicates that this is a comparatively stable shore. This shore is entirely protected by sea-walls which are built at about the mean high water line. There has been both accretion and erosion, with erosion predominating. Between 1893 and 1946, there has been accretion along the mean low water line.

d. Changes Between Profiles 15 and 20. - The mean high water line along the tombolo has been relatively stable, experiencing periods of erosion and accretion, with accretion predominating near the base of Little Nahant, Profiles 18 - 20. Along the northerly part of the beach, the mean high water line prograded about 80 feet between 1847 and 1894, retrograded about 80 feet to its initial position between 1894 and 1919, and again prograded about 80 feet between 1919 and 1946. Along the southern part of the beach, a similar movement has occurred, except that the 1946 mean high water line is about 800 feet seaward of the 1919 mean high water line. The mean low water line retrograded approximately 100 feet between 1849 and 1894, and has prograded approximately 200 feet between 1894 and 1946.

e. Changes Between Profiles 20 and 24. - Both the mean high and mean low water lines indicate a stable shore with little change having occurred since 1894. The greatest changes have been effected along the mean low water line, which moved seaward for a distance varying from 100 to 200 feet.

30. Profiles. - Development of comparative profiles was not possible since the profiles have been surveyed but once, that survey being made for the study in 1945-46. Investigation of changes in beach elevations along the base of the sea-walls was possible through comparison of surveys made for the construction of the sea-walls, and the survey made of the profiles. The following tabulation shows changes that have been effected in beach elevations at the base of the sea-walls since the walls were constructed.

TABLE A - CHANGE IN BEACH ELEVATIONS AT BASE OF SEA-WALLS

(Elevations In Feet Above Mean Low Water)

Profile	Elevation Prior To Wall Construction		1945-1946 Elevation		Change at Base of Wall	
	Date	Elevation	At Wall	10 Ft. From Wall	Total (Feet)	Average Annual Change (Feet Per Year)
1	1905	11.1	10.3	9.0	-0.8	-0.02
2	1905	9.8	11.1	10.6	+1.3	+0.03
3	1905	15.3	13.4	12.4	-1.9	-0.05
4	1901	12.2	14.0	12.0	+1.8	+0.04
5	1901	15.8	11.0	10.3	-4.8	-0.11
6	1901	16.3	8.3	8.2	-8.3	-0.18
7	1901	14.6	6.7	7.3	-7.9	-0.18
8	1901	12.3	5.4	5.4	-6.9	-0.15
10	1907	10.4	7.5	6.8	-2.9	-0.07
12	1907	6.6	6.0	6.0	-0.6	-0.02
13	1907	12.6	9.2	9.1	-3.4	-0.09

The following tabulation is a summary of elevation changes shown in Table A, arranged to show areas in which maximum and minimum changes have occurred.

TABLE B - AVERAGE ANNUAL RATE OF CHANGE IN ELEVATION OF BEACH AREAS AT BASE OF SEA-WALL

Area	Record Period (Years)	Average Change in Elevation (Feet)	Average Annual Change In Elevation (Feet Per Year)
Profiles 1 - 3	41	-0.47	-0.01
Profiles 4 - 8	45	-5.22	-0.12
Profiles 10 - 13	39	-2.30	-0.06

The above tabulations show that erosion has been generally effected immediately adjacent to the base of the sea-wall, with the greatest erosion occurring on the north side of Red Rock between Profiles 4 and 8.

31. Offshore Depth Changes. - a. General. - Plates A-3 to A-5 show the 6, 12 and 18-foot offshore depth curves developed in the area by the U. S. Coast and Geodetic Survey, from surveys made in the years 1846-47-48, 1853-54 and 1895, and the 6 and 12-foot offshore depth curves developed from the profiles surveyed by the Boston District, in 1945-46. The movement of these depth curves may be considered for the same beach sections as utilized in Paragraph 29 for the study of shore line changes.

b. Profiles 1 - 9. - Between 1853 and 1895, the 6-foot depth curve generally moved seaward, an average distance of 200 feet south of Profile 4, while it moved landward an average distance of 150 feet north of Profile 4. Between 1895 and 1946, the 6-foot contour moved landward about 150 feet, with the result that since 1853, there has been a net erosion north of Profile 6, and a net accretion south of Profile 6. Between 1853 and 1895, the 12-foot contour generally moved seaward 150 feet, and between 1895 and 1946, it moved landward an average distance of 150 feet. This movement was not continuous along the entire length of the depth curve, so that the net result since 1853, has been accretion north of Profile 7, and erosion south of Profile 7. Sufficient data are not available to consider the movement of the 18-foot depth curve in this area. The resultant movement along the 6 and 12-foot contours, indicates a relatively stable offshore area, with accretion and erosion tending to balance themselves. It is to be noted that areas of erosion on one contour correspond nearly to areas of accretion on the other contour.

c. Profiles 9 - 15. - There was little movement of the 6-foot contour between 1846 and 1853. Between 1853 and 1895, the 6-foot contour moved landward 200 to 500 feet, and this movement continued through to 1946, by an additional landward movement averaging 50 feet. The greatest erosion occurred at the southerly end of the area. The movement of the 12-foot contour followed that of the 6-foot contour, evidencing little movement between 1846 and 1853, moving landward an average distance of 250 feet between 1853 and 1895, and moving landward an additional average distance of 100 feet between 1895 and 1946. There was little change between 1846 and 1853, along the 18-foot contour. Between 1853 and 1895, there was accretion in the southerly part of the area, and erosion in the northerly part, the two movements balancing each other, and resulting in contour movements varying up to 500 feet. The resultant movement in offshore depth in this area has been erosion along the 6 and 12-foot contours, and stability along the 18-foot contour.

d. Profiles 15 - 20. - The 6-foot contour remained stable between 1846 and 1853. From 1853 to 1895, the 6-foot contour moved landward for distances varying up to 400 feet north of a point midway between Profiles 17 and 18, and south of this point, moved seaward for distances varying up to 400 feet. Between 1895 and 1946, the 6-foot contour moved less, the movement averaging 100 feet, being landward north of a point near Profile 16, and seaward south of that point. The net result of these movements since 1835, has been erosion north of Profile 17, and accretion south of this profile. The 12-foot contour remained relatively stable between 1846 and 1853, following a meandering course in reference to the shore line. During the period 1853 to 1895, the 12-foot contour realigned itself in a position paralleling the shore line generally as far seaward of the shore line as the most distant points of the earlier contour. This realignment resulted in seaward movement of the 12-foot contour varying up to 600 feet. Between 1895 and 1946, the 12-foot contour was stable, showing both accretion and erosion generally balancing each other, with the average movement in contour position being less than 100 feet. The net result of all movement along the 12-foot contour since 1846, has been accretion. The movement of the 18-foot contour has followed the pattern of that of the 12-foot contour, being stable between 1846 and 1853, and moving seaward between 1853 and 1895, to align itself parallel to the shore line at a point near the most seaward points on the earlier contours. This realignment has resulted in movements varying up to 200 feet seaward. The resultant movement of offshore depth curves in this area indicates that the greatest changes have occurred north and south of Profile 17, while changes have been relatively slight in the vicinity of that profile; that erosion has been affected in the more shallow depths north of Profile 17; that accretion has been affected in all depths south of Profile 17, and in the deeper waters north of Profile 17; and that the contours tend to align themselves parallel to the shore line.

e. Profiles 20 - 24. - In 1846 and 1853, the 6-foot depth curve approached the shore of Little Nahant near its point of junction with the tombolo in the vicinity of Profile 20, having experienced about 50 feet of erosion between the two years. Between 1853 and 1895, the 6-foot depth curve had prograded so as to approach Little Nahant at the outer point near Profile 22, resulting in a seaward movement of the contour varying up to 800 feet. This seaward movement continued between 1895 and 1946, varying up to 100 feet. Since 1853, there has been constant accretion along the shore of Little Nahant. The movement pattern of the 12-foot contour follows that of the 6-foot contour, with movements made over smaller distances. The position of the 12-foot depth curve in

1946, was generally 400 feet seaward of the 1853 position. The 18-foot contour in 1846 and 1853, swung inshore on either side of Little Nahant to bring a channel of deep water in toward the tip of the headland. Between 1853 and 1895, this channel of deeper water was cut off so that the 18-foot contour passed by Little Nahant at a point approximately 1600 feet from the tip of the headland. The seaward movement of offshore depth curves indicates extensive accretion in this area, with the various contours tending to align themselves with the axes of the tombolos.

32. Consideration of the changes in positions of the several offshore depth curves throughout the entire area between Blaney Rock, Profile 1, and Little Nahant, Profile 24, indicates that the area is approaching stability. The depth curves for the years 1846 and 1853, follow meandering courses, influenced by local shore features, such as Red Rock and Little Nahant. The depth curves for the later years, 1895 and 1946, follow smooth curves, closely paralleling the general shore line of the mainland and the axis of the tombolo. With the exception of an area adjacent to Red Rock, the realignment of the contour has been accomplished by the seaward movements resulting from accretion. In the area adjacent to Red Rock, the realignment was accomplished through erosion, the erosion being considerable at the 6-foot depth, and almost negligible at the 18-foot depth. Though offshore depth curves have moved great distances between the several surveys, it should be noted that the slope of offshore areas generally varies between 1 on 100, to, 1 on 150, which means that a few inches change in elevation at one point will result in a great horizontal movement in contours.

33. Littoral Drift. - a. The shore of Lynn-Nahant Bay is acted upon by waves produced by dominant northeast winds and storms. The configuration of the coast is such that these waves upon reaching the headlands of Phillips Point and Nahant, are refracted into the bay. This results in the waves creating currents moving northerly along the northerly part of the bay, and south along the southerly part of the bay, the currents transporting materials from the center section of the bay toward either end. This effect is indicated by the position of the shore lines and offshore depth curves, by accretion of materials in the vicinity of Profile 3 at the north end of the beach, and in the vicinity of Profile 20 at the south end of the beach, and by the study of the position of pocket beaches north and south of the study area.

b. The original coast line comprised the mainland and two till mantled rock islands, Big Nahant and Little Nahant. Material working along the mainland and around the islands, tied the islands together and to the mainland. Mr. D. W. Johnson, in, "New England Acadian Shore Line", notes that the Nahant tombolo has been frequently cut through by the sea. There was apparently sufficient material available to close the cut, and to maintain the closures. In recent years, the tombolo has not been cut across, though storms have washed over it.

34. The cutting back of headlands to bare ledge rock, and the erection of protective works along the exposed shore of the headlands and mainland, has shut off the onshore supply of materials for beach building. There are no large sources of material north of the area upon which the dominant coastal north to south drift can act. Any amount of material reaching the Lynn-Nahant beach from northerly beaches will be offset by the movement of materials

out of the bay to beaches south of the area. Some materials are transported onto the beach from offshore depths. Stones bearing kelp are found on the beach, and during storms quahaugs are washed upon Nahant Beach, both effects serving to indicate a disturbance of the ocean bed, and the transportation of materials onto the beach. During storm periods, great changes are effected in beach elevations which revert to their normal elevation under dominant material moving forces. The storm of November 28-30, 1945, was one such storm, and stones were piled up against the sea-wall north of Red Rock, for heights of 2 to 3 feet. These stones were deposited on a section of beach normally of hard-packed sand.

VI. EXISTING PROTECTIVE STRUCTURES
(See Plate A-1 and Figures A-1 to A-3)

35. Structures and Ownership. - The mainland coast of the study area is continuously protected by concrete and masonry sea-walls. With the exception of the walls on the outer end of Blaney Rock, which are privately-owned, all sea-walls along this coast are owned by the Metropolitan District Commission. The base of the dune along the Nahant tombolo is partially protected by riprap placed by the Metropolitan District Commission. The base of Little Nahant is protected by privately-owned sea-walls except where exposed ledge affords a natural bulwark against the sea. A complete description of these structures is contained in Appendix I, supplemented by details of principal structures shown on Plate A-1 and in Figures A-1 and A-3.

36. Private Walls at Blaney Rock. - Seaward of the northerly limit of the Metropolitan District Commission Reservation at Blaney Rock, the base of the cliff is protected by a series of rubble masonry walls. The tops of these walls are generally 20 feet above the beach, but this extreme height is provided to retain the fill extending the level area of the headland. One wall is only five feet high and evidences no damage from waves. The shore fronting these walls varies from exposed ledge at its extreme point to hard-packed sand and boulders near the inner end of the headland.

37. Metropolitan District Commission's Concrete Sea-Wall Profiles 1 to 14 (Figures A-1 and A-3). - The concrete sea-wall between Blaney Rock and Nahant Street, approximately between Profiles 1 to 14, was constructed principally in 1904 and 1907. The section of wall around Woodbury's Point, southwest of the tower bastion, was constructed in 1931 after a large section of an existing rubble wall and riprap slope paving had been washed out. The concrete wall is a gravity-type sea-wall having a curved face above the elevation

of mean high water and a vertical face below that elevation. South of Profile 10, there is a transition curve between the vertical and curved surfaces. A projecting coping is provided along the top of the wall. The original wall section did not include a toe wall except between Red Rock and the tower bastion. A toe has been added to prevent undermining. The wall is founded on clay and gravel, except where ledge outcrops occur in the vicinity of Red Rock and in the area of Profile 3 where the wall rests on a double row of wood piles. The thickness of the wall was reduced in certain sections around Red Rock and Woodbury's Point by utilizing existing masonry walls for backing. The wall is backed with earth fill. Collector pipe drains were generally installed along the clay line in back of the wall, the drains discharging into outfalls from highway catch basins with the outfalls passing through the wall to rock filled blind drains constructed 3-1/2 feet below the beach surface. The blind drains were 8 feet from the wall and have generally been abandoned because of erosion of the beach. Access to the beach from the top of the wall is provided by a series of steps and ramps leading from projecting bastions. The bastion between Profiles 3 and 4 also serves as the outlet for a large box culvert.

38. The elevation of the top of the concrete sea-wall is generally 20.5 to 22.6 feet above mean low water, though it varies between 17.3 and 28.6, partly following the topography of the adjacent cliff. Table C in paragraph 41 lists principal elevations of the wall. The sea-wall being generally located at or seaward of the mean high water line of a beach on which there is continuous surf, is subject to wave impact during high water. This attack is greatly intensified during storms and abrades the lower portions of the wall with materials carried in the wave wash. This attack has been progressive and resulted in severe damage. The damage comprises cracking and spalling of the sur-

face, breaking up of copings, toe walls, bastions, and steps. There has been constant erosion at the base of the wall for most of the wall's length necessitating the building and deepening of toe walls. Some of the toe walls have been extended to mean low water level. The erosion has also uncovered many of the blind drains originally on the beach, necessitating their removal. Settlement also has broken up the drains so that today only four of them remain, and these are scheduled for early removal. Where these drains are removed, the old outlets leading to them through the wall are sealed and new outlets provided for highway drains about four feet from the top of the wall. The steps from the bastion down the face of the wall suffer particularly severe damage, probably due to the manner of step construction which results in the breaking up of the waves at that point and the absorption of wave energy. These steps have been partially replaced with ramps which do not suffer such extensive damage.

39. There have been constant repairs made to the sea-walls, both by contract work and by maintenance forces. Holes have been filled, copings reconstructed, and toe walls constructed, rebuilt, and extended. Extensive repairs appear to have first been accomplished in 1933 and such work has been in progress since that time, the last major repair program being in 1945, when major holes were patched with reinforced concrete along the entire length of the wall, 520 feet of toe wall constructed, steps on two bastions repaired, and a new ramp and new steps constructed.

40. The beach fronting the sea-wall varies in composition. There are seasonal variations in beach elevations at its base, being lower in winter, in addition to the general erosion experienced there. Storm tides cover the beach with stones, piling them 2 to 3 feet deep at the base of the wall, but these stones are later removed by the waves. Between Profiles 1 and 8 the beach is very flat and is of hard-packed

sand in all areas, except at Profile 3, where the backshore is soft sand. Some stone is always present at the base of the wall at Profile 4. Around Red Rock the beach is stony with some boulders, except at the outer end where there are ledge outcroppings. Between Red Rock and the tower bastion the beach is hard-packed gravelly sand with a shingle deposit at the base of the wall. The waves continually move this shingle against the wall and wear away the concrete to leave the reinforcing steel exposed in the toe wall. Southwest of the tower bastion the beach is of coarse sand, stones, and boulders. Riprap has also been placed in the area to protect the base of the sea-wall. In addition, the remains of an old wood pile breakwater projects above beach level. The beach fronting the concrete wall south of Woodbury's Point is generally stony.

41. The following tabulation lists the principal elevations of the wall and elevations of the adjacent beach. All elevations refer to mean low water and were determined by the Boston District survey in 1945-46, except the elevations of the bases of the sea-wall and toe wall and the top elevation of the north end of the wall. These latter elevations were taken from construction drawings. A tabulation of original beach elevations and a comparison of beach elevations is given in Table A in Paragraph 30.

TABLE C

PRINCIPAL WALL AND BEACH ELEVATIONS
(Feet above Mean Low Water)

Profile	Wall		Toe Wall	Beach in 1946		Remarks
	Top	Base	Base	At Wall	10' from Wall	
North End	28.6	4.4	1.55			Toe wall original construction
1	25.0	7.6		10.3	9.0	
2	18.5	5.6 6.6		11.1	10.6	Wall on Piles
3	17.3	7.6 9.6		13.4	12.4	Wall on Piles
4	19.8	7.6		14.0	12.0	
5	20.5	9.6	2.1	11.0	10.3	Toe wall added
6	20.5	9.6	3.0	8.3	8.2	Toe wall added and extended
7	21.5	8.6	6.0	6.7	7.3	Toe wall added
8	22.5	6.5	0.6	5.4	5.4	Toe wall added and twice extended
9	22.5	16.8		18.3	18.4	Ledge
10	22.5	5.5	1.5	7.5	6.8	Toe wall original construction
11	22.5	5.2		8.1	6.4	Addition made to toe wall between Profiles 10 and 11
12	22.0	5.4	3.0	6.0	6.0	Toe wall original construction
13	18.6	9.4	2.6	9.2	9.1	Toe wall original construction

The above tabulation of elevations show that on 10 profiles, the present beach elevation within 10 feet of the wall are not over 1.5 feet above the elevation of the base of the wall and at 4 profiles the present beach elevations are below that of the base of the wall. The danger of undermining has been relieved at most profiles by the construction of toe walls, but at Profile 11, the danger still exists.

42. The concrete sea-wall has protected the adjacent coast from all but minor damage, comprising washouts of walks and lawns, and destruction of benches and railings. The wall has not prevented erosion of the fronting beach and has required the construction of toe walls to prevent undermining. The wall in itself has been subject to severe damage and in spite of continued and recent repairs is in a very poor condition showing cracked and spalled concrete areas, broken steps, and broken toe walls.

43. Metropolitan District Commission's Rubble Masonry Sea-Wall, Profiles 14 to 15 (Figure A-3). - The rubble masonry sea-wall between Nahant Street and the Lynn-Nahant Town Line, approximately Profiles 14 to 15, was constructed prior to 1900 before its acquisition by the Commission. It has a top elevation varying from 18.6 to 17 feet above mean low water. It has suffered from storm attack. The bastion steps were repaired in 1941, and the entire bastion rebuilt in 1945. A toe wall has been constructed in front of this wall. When the wall was repaired, the stones were set in mortar. The southerly end of the wall is tied to firm land by an 80-foot return wall.

44. Metropolitan District Commission's Riprap, Nahant Beach Parkway. - The seaward face of the Nahant tombolo is not generally protected from wave attack. The only protective structure is at the northerly end of the tombolo where approximately 4700 feet of riprap revetment has been placed at the toe of the sand dune. This riprap consists of stone varying up to one cubic

yard in size and was placed in 1935 as a pavement 10 feet wide. The riprap has stabilized the toe of the northerly section of the dune. The toe of the southerly unprotected section of dune was cut back distances up to 20 feet during the storm of November 28-30, 1945. Shore protection for the harbor side of the tombolo is discussed in Appendix A-I.

45. Private Sea-Walls, Little Nahant. - The base of Little Nahant is protected by a continuous series of short masonry and concrete walls which were privately constructed over 28 years ago. They have not generally suffered severe damage although two require rebuilding.

VII. PLANS OF PROTECTION

(See Plate A-6)

46. Analysis of Principal Features of Problems. - The Lynn-Nahant beach is the result of the erosion of two islands and a mainland cliff and the construction of a tombolo from the eroded materials to tie the islands to the mainland. The erosion of the islands and mainland has been arrested by the construction of sea-walls and the exposure of ledge rock. The recent history of the beach indicates that the mainland sea-walls protect the coastal cliff from any severe damage, and that there is constant erosion at the base of the wall. The offshore areas fronting the wall are generally stable. The wall suffers from continuous spalling, disintegration, and breaking of concrete and in spite of periodic and extensive repairs is in a generally poor condition. Complete sections of the wall have never been demolished. Erosion of the beach at the base of the wall has necessitated the construction of toe walls to prevent undermining. The tombolo area of Nahant Beach has been generally stable, allowing the construction of a paved walk along the top of the sand dune and the construction of Masonry fireplaces and tables at the seaward toe of the dune. The storm of November 28-30, 1945, was the first storm in a number of years to affect the beach seriously, and the seaward face of the dune, where not afforded riprap protection, was cut back 15 to 20 feet. The beach is generally of hard-packed sand for the entire length except that the backshore area for the northerly half of the tombolo and the adjacent mainland near Nahant Street (between Profiles 13 and 14) is stony. The stones are densest and of the greatest size in the area of Profile 16, fronting the Public Bathhouse.

47. Objectives of Study. - The cooperating agency's objective in the study is to determine the best method of preventing further erosion, stabilizing and improving the beaches, and protecting the sea-walls. The problem at Lynn-Nahant beach resolves itself into three separate parts as follows:

a. Corrective measures to be applied to the existing mainland sea-walls.

b. Improvement of beach adjacent to the bathhouse..

c. Protection of the tombolo.

48. Plan for Maintaining the Concrete Sea-Wall, Profiles 1 to 12. - The concrete sea-wall between Profiles 1 and 12 has been entirely successful in protecting the coast since the wall was constructed. The maintenance of this wall is therefore the best assurance for continued protection of the coast. At present, the face of the wall is in a very poor condition, exhibiting numerous spalled, disintegrated, and cracked, areas. Damaged areas were repaired periodically with new reinforced concrete, but such repairs did not reinforce adjacent weakened areas which later spalled, cracked and disintegrated. The wall needs a complete new armoring surface which will cover the present surface, thereby filling all holes and cracks and protecting the present weakened surface from further damage. This armor may be provided by facing the wall with stone blocks, by casting a new reinforced concrete surface or by applying a dense concrete over the structure by the airgun method, commonly termed, "guniting". The gunite would require mesh reinforcement.

49. The facing of the wall with stone blocks would involve the construction of a foundation for the blocks, the accurate cutting and setting of stone to the curved surface of the wall, and the dowelling of the blocks to the wall and to each other. The construction of a new concrete surface would require extensive form work to form the curved

surface, considerable care in placing the concrete due to the thin section and the reinforcing steel, and extensive hand finishing after the forms were removed. The gunite would eliminate all difficulties arising from the shape of the wall and from the difficulties due to anchoring the facing material with dowels and reinforcement. Regardless of the method employed, prior to armoring the wall, all cracks in the existing wall will have to be raked out, all bad concrete cut out, all holes filled with new concrete properly anchored to the existing concrete, and all damaged steps and ramps rebuilt. It is considered that the gunite surface, 3 inches thick, applied over a steel mesh, secured to the existing wall will provide the most economical, satisfactory armor for the wall. Sections and details of this work are shown on Plate A-6.

50. Erosion of the beach at the base of the sea-wall has endangered sections of the wall. The extent and rate of this erosion are shown in Tables A and B in Paragraph 30. Several types of toe walls have been constructed at various locations to prevent the undermining of the main sea-wall. A study has been made of additional steps to be taken to ensure the stability of the wall. The beach elevation could be raised, but the beach would have to be built up with artificial fill since there is no littoral drift present for natural beach-building. The existing beach is a very hard-packed sand beach having a slope in the upper tidal range varying from 1 on 45 to 1 on 75 and a slope in the lower tidal ranges and offshore area varying from 1 on 100 to 1 on 150. These very flat slopes would necessitate very large quantities of fill for artificial beach-building. It is not considered necessary that a beach be built at this point for recreational purposes since the present beach is adequate for local residential use and large beach areas for transient bathers' patronage are provided south of Profile 12 and at Revere Beach.

It is therefore considered that the construction of an artificial beach is not justified in this area.

51. Consideration was given to the placing of riprap at the base of the wall to prevent erosion, but since the high water line is at or near the wall it was not deemed advisable to further reduce the width of the beach by such construction.

52. The protection of the sea-wall thus resolves itself into the construction of toe walls to such depths as will prevent undermining. Many toe walls have been built to date, some of which have had to be replaced or rebuilt and some of which require repairing and rebuilding. These toe walls are of various designs and depths. This construction has resulted in a somewhat continuous, irregular shaped, toe wall which alters the basic shape and design of the curved wall. It is believed that it is undesirable to break up the smooth lines of the original structure. A study was made of the shapes, sizes and depths of these toe walls to determine if they could be removed and replaced by a continuous steel pile cut-off wall which would return the profile of wall to that of the original design. It was found that many of the present toe walls provide adequate protection for the main wall and are of such size that their removal would not be economically justified. New or additional protection is needed in certain areas. Where such protection is required, it is recommended that it be provided by means of a steel sheet pile cut-off wall driven to elevation 0.0 at a point close to the present structure and, where exposed above beach elevations, covered with gunite to bond and blend with the recommended gunite armor surface of the main wall. Where existing toe walls are adequate, it is recommended that all projecting corners be cut back and the wall built up as necessary to form a smooth curve continuous with the main seawall. Details of the treatment of toe walls are shown on Plate A-6.

53. The study of toe wall requirements indicated the following treatment is presently required:

a. Profile 1. Area. - No new toe wall is required in this area. The northerly 50 feet of the wall was constructed with a toe wall to elevation 1.6 above mean low water. The rest of the wall in the area has no toe wall. At Profile 1, the beach under the present rate of erosion will require 72 years to reach the base of the wall.

b. Profile 2-3 Area. - No new toe wall is required in this area. The wall is partly supported on wood piles. At Profile 2, the beach is building up at the rate of .03 feet per year. At Profile 3, the beach under the present rate of erosion of .05 feet per year will require 56 years to reach the base of the wall.

c. Profile 4 Area. - No new cut-off wall is needed. The beach is building up at the base of the wall.

d. Profile 5-8 Area. - New cut-off walls are needed wherever existing sea-walls or toe walls do not extend below elevation 6.0 above mean low water. Existing toe walls require trimming to present a smooth curve joining that of the main sea-wall. At the present rate of erosion, it will require 39 years for the beach to reach the base of existing toe walls extending below elevation 6.00 above mean low water.

e. Profile 9 Area (Red Rock). - The wall is founded on ledge. Footing has been reinforced, but requires trimming to lines of the original wall.

f. Profile 10 to 12 Area. - Requires a new cut-off wall from the base of Red Rock, near Profile 10, to the base of Woodbury's Point, near Profile 12. There is a toe wall between Red Rock and the tower bastion, but this toe wall needs replacing because disintegration of concrete exposes all the reinforcing steel. There is no toe wall southwest of the tower bastion and the present rate of erosion will undermine the wall in about 15 years.

The depth to which new steel sheet pile cut-off walls are to be driven was selected after giving consideration to the slope of the beach, the present rate of erosion and the depth of existing cut-off walls. In the future, it may be necessary to extend the depth of cut-off walls not now recommended for such work. At all times, local authorities should consider the stability of the sea-wall, frequently checking the same in relation to existing beach elevations. In the event that any section is found to be in danger of overturning or displacement, the width of the beach at high water may be sacrificed to the necessity of stabilizing the wall and heavy riprap may be placed in front of the endangered sections.

54. Improvement of Beach, Profile 12 to 16 Area. - The coastal cliff between the base of Woodbury's Point, near Profile 12, and Nahant Street, near Profile 13, is protected by a concrete sea-wall, and between Nahant Street and Profile 15, is protected by a masonry wall. These walls have been successful in protecting the cliff. However, the walls are subject to recurring damage. Erosion at their bases has necessitated the construction of toe walls to prevent undermining. The mean high water line is near or at the base of the walls. The walls require protection from wave attack and from undermining through beach erosion. The beach is stony and contains boulders.

55. There is no shore protection between the south end of the masonry wall at Profile 15 and the riprap protecting the sand dunes, commencing about 500 feet south of Profile 16. The unprotected area fronts the state operated bathhouse and is the main bathing beach. The backshore beach is very stony and is unsatisfactory for recreational use. The stones are contained in the existing beach materials and are not transported to the area. The backshore is very low in elevation, being 15.5 feet above mean low water along a line connecting the protective structures north and south of the area. Elevations of 17 to 18 feet occur 25 to 50 feet in the rear of the above-noted line. This low area allows storm waters to wash onto the adjacent highway and to reach points flanking adjacent protective structures.

56. The area between Woodbury's Point and the sand dunes may best be improved by the construction of a beach of sufficient width and height as to place the mean high water line seaward of existing

structures, to cover the objectionable stones, and to prevent wave attack in the area behind the sea-wall riprap line. Such a beach must be constructed of artificially placed sand fill since there is no littoral drift available for beach building. Details of the required beach are shown on Plate A-6. The artificial beach is designed to be built of sand having the same gradation as the beach material along the Nahant tombolo. The fill has an elevation of 18.0 feet above mean low water at the sea-walls and along a line connecting the sea-walls and riprap. The beach slope above mean high water is 1 on 17 and below mean high water, 1 on 55. These slopes were determined from a study of slopes existing along the tombolo.

57. The artificial fill will provide a dry beach 150 feet wide above mean high water. The dry beach will be up to 75 feet wider in the present bathing area and from 75 to 150 feet wider in front of the sea-walls. This increased width represents a 100 per cent increase of dry beach area at mean high water and the extension of the recreational beach 1500 feet to Woodbury's Point. The wider beach and the burying of the stones and boulders with sand will result in a desirable bathing beach capable of accommodating twice as many patrons as can be accommodated now.

58. The raising of beach elevations to 18.0 feet above mean low water along the line between the sea-walls and riprap will afford the bathhouse area the same protection from flooding as has been provided the adjacent area by the sea-walls. This protection has proven adequate. The effectiveness of this protection will further be increased by the new wide backshore beach. Waves will break from 0 to 75 feet seaward of their present plunge points and expend their energy on the backshore.

59. The existing sea-walls between Woodbury's Point and Profile 15 will be practically covered by the sand fill. The moving of the mean

high water line to a point 150 feet seaward of the sea-walls will cause waves now attacking the wall to expend their energy on the backshore slope of the beach. All danger of undermining of the walls will be removed by the fill. The artificial fill thus provides complete protection for the sea-walls and eliminates the need of repairing damaged sections of the wall or the construction of toe walls.

60. Groins are not believed to be required to maintain the fill placed in this area. The study of the existing beach indicates it is relatively stable and that littoral drift reverses its direction along the beach. The northerly end of the fill has been extended to Woodbury's Point which will serve as an anchor for the fill in that area. The fill has been designed to be placed in continuation of the contours of the tombolo beach at its southerly end. Transitional sections are provided at both ends of the artificial beach so as to blend the fill onto adjoining areas.

61. Suitable materials for fill apparently cannot be obtained by hydraulic dredging within safe working or practical pumping distance. Materials in Lynn Harbor appear to contain large quantities of clay, silt, and muck. Materials having the same characteristics as sand now present on the tombolo beach are believed to be obtainable at pits located 12 to 25 miles from the beach, and may be transported overland or by barge to the site.

62. It is essential that the artificially placed sand fill be maintained generally at or above the designed grades. This condition can best be accomplished by the establishment of a permanent maintenance program under which materials eroded from the area will be periodically replaced and any severe storm loss that may occur be immediately replaced. The beach built and maintained to the new dimensions should provide

effective protection to the existing sea-walls, reduce destructive energy of waves reaching backshore areas, prevent substantial wave wash from passing over and beyond the backshore area, and greatly increase and improve the recreational usability of the beach in the area.

63. Protection of Nahant Beach. - The maintenance of Nahant Beach is dependent upon the maintenance of the sand dune to prevent storm waves from breaching the narrow neck of land and beach materials from being washed into Lynn Harbor. This type of protection can only be provided by a self-supporting barrier erected seaward of the dune. The protection of the dune by slope pavements and riprap is not recommended since any washout of the dune by either wave wash passing over the dune, as occurs in great storms, or by attack from waves from Lynn Harbor, will result in the displacement of the pavement or riprap and the eventual breaching of the dune.

64. Protection of the dune may best be accomplished by the construction of a free standing stone mound at the toe of the dune as detailed on Plate A-6. The top elevation of the mound is 18.0 feet above mean low water which is the same elevation as the sea-walls adjacent to the bathing beach and the elevation of the proposed sand fill at the bathing beach. This elevation is 3 feet above maximum recorded high water in Boston Harbor, which record is indicative of extremely high water elevations to be anticipated in adjacent waters. The mound is located along the 15-foot contour and has a footing three feet deep. The mound has a top width of 3 feet and side slopes of 1 on 1 and is designed to be constructed of run of quarry stone with a seaward face of stone having minimum weight of 1000 pounds. Fill is to be placed between the mound and the dune. Access to the beach and existing fireplaces is provided by stone steps constructed of cut blocks 12 inches by 24 inches by 5 feet placed to form steps having 12" risers and 18"

treads. The steps are continued to the base of the mound to provide for changes in beach elevation. The mound is to extend from the end of the dune near Profile 16 to high ground at the base of Little Nahant near Profile 20.

65. The stone mound was selected as the desirable type of structure because of its flexibility for meeting foundation conditions, the ease with which settlement may be rectified, and in order that the existing riprap at the northern part of the tombolo may be utilized. The total amount of stone required is estimated to be 30,000 tons, of which 4,500 tons are available from existing riprap. It is also estimated that sufficient materials are obtainable from the required excavations to accomplish all filling required in back of the mound.

66. The construction of the mound as designed will result in an effective barrier to prevent the loss of the sand dunes from wave attack, the washing of beach materials into Lynn Harbor, and the breaching of the tombolo. The location of the mound at the 15-foot contour places it from 100 to 200 feet behind the mean high water line. The mound will not be subject to attack except under extreme storm conditions. It is expected that the dunes will increase in size when their seaward base is protected from wave attack, such growth tending to provide additional protection from wave wash passing over the dunes to inundate Nahant Road.

VIII. ECONOMIC ANALYSIS

67. Basis of Analysis. - a. Estimates of first cost have been made for all plans of improvement and protection, and are given in Appendix III and summarized in Paragraph 68.

b. An estimate of annual benefits has been made only for the work recommended between Woodbury's Point and Little Nahant. This estimate is given in Appendix IV and summarized in Paragraph 69.

c. A detailed economic analysis has not been prepared for the work recommended between Woodbury's Point and Blaney Rock, since the work comprises maintenance of existing structures and no Federal participation is involved. The maintenance of the existing walls is the responsibility of the owners and local authorities. The benefits to be derived from the project are the maintenance of the benefits which resulted from the initial wall construction, the reduction of future maintenance, the insurance of the future service and stability of the walls, and the protection of the public investment in the developement of the reservation. With the exception of the reduction of maintenance costs, these benefits are such that assignment of monetary values is not readily accomplished. The non-Federal annual carrying charge of the recommended repair computed at an interest rate of 3-1/2 per cent and amortized over a 25-year period is $8,400. With an estimated annual future maintenance cost of $2,600, the total carrying charge amounts to $11,000. The carrying charge is less than the average annual cost of repairing storm damage, $12,000. Public property has an estimated valuation of $1,512,000, comprising land valued at $120,000, sea-walls at $1,200,000 and roads at $192,000. Private property fronting the shore drive has an assessed value of $1,133,000 and marginal property within 1000 feet of the drive, but exclusive of frontal property, has an assessed valuation of

$5,741,000. The total annual tax return on the property is $301,000. The ratio of annual carrying charges to annual costs of repairing storm damage, and the value of public property and private property to be maintained through the repairs of the sea-wall are sufficient to justify the accomplishment of recommended repairs by local interests.

68. Estimates of First Costs. - The first cost of the plans of protection and improvement discussed in Paragraphs 48 to 66, inclusive, are estimated to be as follows:

a.	Repair of Concrete Sea-walls, Profiles 1-12	$138,000.
b.	Improvement of Beach, Profiles 12-16	366,000.
c.	Protection of Nahant Beach, Profiles 16-20	98,000.

Detail estimates of above costs are presented in Appendix III.

69. Estimates of Benefits. (See Appendix IV) a. General. - The benefits discussed herein are the benefits to be derived from the recommended plans of improvement for that part of Lynn-Nahant Beach lying between Woodbury's Point and Little Nahant. The benefits result from direct and indirect damages prevented, increased recreational facilities, increased property values, and the prevention of isolation of an entire town, including the isolation of major harbor defense posts.

b. Average Annual Direct Damages Prevented. - Estimated average annual expenditures to repair direct damages over the period of record have been:

Federal	$ 0
Non-Federal Public	14,050
Private	0
Total	$ 14,050

c. Indirect Damages Prevented. - The inundation of the Nahant tombolo results in the complete isolation of the entire Town of Nahant, population 1800. During the period of inundation and the time necessary to effect repairs of highway washouts, normal community activity is disrupted through lack of transportation to the mainland. The reconstruction of the highway, parking place and Lynn Harbor shore protection as accomplished in 1947, reduces the damages of inundation and washouts from Lynn Harbor, but does not affect the attack from Nahant Bay. After storms in the fall of 1947, it was noted that water had flowed through the gullies between dunes onto the new parking areas. This condition has been also noted after subsequent storms. The construction of the proposed stone mound will arrest this action and prevent flooding of the highway from the bay. Monetary evaluation is not made of the losses incurred by the Town during the inundation periods, as such losses involve complex items not readily ascertained, and depend upon the time and length of occurrence. The financial losses involved comprise lost business, lost wages by those who are unable to reach their work, and the expense to those who are unable to reach their homes. During severe storms, this damage can reach considerable proportions.

d. Increased Earning Power of Property Resulting from Shore Protection. - All property subject to damage is publicly owned, comprising the Metropolitan District Commission's Reservation and the Nahant Road. While protection from storm and wave attack will increase its value, its public ownership will be retained and no return on the increased value can be realized. Hence no benefit is evaluated for this item. Private property will not increase in value due to the construction of shore protection in this area.

e. Recreational Benefits. - The improvement of the bathhouse beach will result in important recreational benefits. The elimination of the objectionable stony beach condition and the doubling of the dry beach area above the mean high water line, will develop a more popular beach, which may be expected to serve approximately twice as many patrons as presently served. This increased patronage will increase the revenue from the small charge made at the bathhouse. The increased patronage will also increase the volume of business for the eating and refreshment stands along Washington Street, adjacent to the bathhouse area, which in turn will increase the rental value of the business property. The rental value of the residential property between Washington Street and Atlantic Terrace on Woodbury's Point will increase because of the construction of the artificial beach in front of the sea-walls, an area which at present is not a recreational area. The stone mound along the Nahant tombolo will not afford direct recreational benefits, though in stabilizing the dune area, it will allow development of better permanent access paths and contingent facilities such as park benches, drinking fountains, etc. The full monetary worth of adequate recreational facilities cannot be evaluated. A partial evaluation of the benefits may be made in terms of increased patronage of the beach and of increased valuation of private property due to the improvement of the beach. This partial evaluation is as follows:

a.	Federal	$ 0
b.	Non-Federal Public	23,250
c.	Private	4,470
	Total	$ 27,720

f. Intangible Benefits. - In addition to the benefits realized by the Town of Nahant through the prevention of indirect damages by the proposed stone mound, as discussed in subparagraph c above, there are other real but less tangible benefits which will accrue from this construction. The present beach is stable and well suited to all types of recreational activities. If the dunes are allowed to be lost, storm waves will roll over the tombolo and sweep the beach materials into Lynn Harbor. The material could be periodically reclaimed by hydraulic dredging, but such a process would be of considerable cost and would probably not provide as satisfactory beach as presently exists. Materials washed into the harbor would also shoal the channel of the Federal project which is adjacent to the tombolo. The loss of the dunes would soon be followed by breaching of the tombolo, with the result that the entire Town of Nahant would be isolated until major repairs were accomplished. The isolation of the entire town at any time creates serious problems of public welfare, since any emergency aid and relief required by a public disaster cannot be given by neighboring communities. The inundation of the single road for a short period can cause the loss of life of sick or injured persons who require emergency treatment in the major metropolitan hospitals. Under certain combinations of conditions, such as a major conflagration at the time of a complete breaching of the tombolo, great losses of life and property can be incurred due to inability to secure outside aid. Should isolation occur during a war period, national security would be imperiled, since access to major coast defense positions would be cut off. Intangible benefits of this type derived from the maintenance of the tombolo, while not susceptible to direct evaluation, are real and important benefits.

70. Federal, Non-Federal Public and Private Interest. - Federal interest in a shore protection project is defined as the benefit secured by the United States as a landowner. Non-Federal public interest is defined as (a) the benefits accruing to a state or political subdivision

thereof as a landowner and (b) benefits accruing to the general public. Private interest is defined as the benefit derived by individuals or non-public groups of individuals on account of the ownership of lands and business enterprises. The total interest in a project is the summation of all benefits accruing thereunder.

a. Public Ownership.

(1) Federal. - The Federal Government owns no property at Lynn-Nahant Beach.

(2) Non-Federal Public. - Non-Federal publicly owned property along Lynn-Nahant Beach comprises land, sea-walls, parks, sidewalks, roads, a bathhouse, and sanitary facilities. All public property is owned by the Metropolitan District Commission, with the exception of the highway to Nahant, which is owned by that town. This public property has the following estimated valuations:

Land	$ 762,000
Sea-walls	1,680,000
Permanent Buildings	75,000
Roads	410,000
Total	$2,927,000

b. Private Ownership. - The assessed valuation of private property and tax income in the Town of Swampscott and the City of Lynn is as tabulated below. This tabulation is made up to show frontal property adjacent to the reservation, and marginal property, property lying within 1000 feet of the reservation, exclusive of frontal property. There is no private property in the Town of Nahant between the Lynn-Nahant Town Line and Little Nahant.

Frontal Property	Assessed Valuation	(1938) Annual Tax Return
Swampscott	$ 272,000	$ 10,320
Lynn	1,259,000	54,400
Marginal Property		
Swampscott	1,379,000	52,400
Lynn	6,379,000	290,880
Totals		
Frontal	1,531,000	62,720
Marginal	7,758,000	345,280
Grand Total	$9,289,000	$408,000

Present sales value of private property in this area is estimated to be 50% above assessed valuations. Estimated sales values are:

Frontal Property	
Swampscott	$ 408,000
Lynn	1,888,500
Marginal Property	
Swampscott	2,068,500
Lynn	9,568,500
Totals	
Swampscott	2,476,500
Lynn	11,457,000
Grand Total	$13,933,500

c. Lands, Easements and Rights of Way. - The improvements proposed herein are planned for construction on lands now publicly owned, except for a short distance at the southerly end of the stone mound along the Nahant tombolo. The proposed mound will require continuation for a short distance over private property to high ground at the base of Little

Nahant, to prevent flanking by flood water. The cooperating agency should be required to obtain such land, rights of way and easements as the final construction plans indicate to be necessary.

d. Benefits and Interests. - The amount of the interest of one agency in a project is the percentage of that agency's benefits to the total benefits to accrue from the project. On the basis of benefits evaluated in Paragraph 69, the per cent of benefits derived by each agency is as follows:

Agency	Annual Benefits	Percent of Interest
Federal	$ 0	0
Non-Federal Public	37,300	89
Private	4,470	11
	$41,770	100

71. Allocation of Costs. - The policy for the allocation of costs is expressed in Public Law 727, 79th Congress, 2nd Session which provides that the Federal Government may contribute a percentage, not to exceed 33-1/3 per cent, of the total cost of construction of works for the improvement and protection of shores owned by States, municipalities, or other political subdivisions, excluding costs of necessary lands, easements and rights-of-way. The federal share of the cost of a project thus becomes the percentage of the total interest represented by the Federal interest plus a percentage of the cost of the non-Federal public interest as allowed under the law. The non-Federal share of the cost is represented by the non-Federal interest in the total interest less the Federal contribution allowed under the law.

72. Federal interest is shown in Paragraph 70 to be zero. Federal participation in the proposed plan of improvement, as determined in Paragraph 75, is one-third of the construction cost. The total Federal share

of the cost of the proposed plan is thus one-third of the construction cost. The non-Federal is two-thirds of the construction cost.

73. Annual Charges. (See Appendix III) The annual carrying charges for the plan of improvement between Woodbury's Point and Little Nahant will be, it is estimated, $28,020. The annual carrying charges have been based upon interest rates of 3 percent for Federal cost, 3-1/2 per cent for Non-Federal cost, and amortization of depreciation and obsolescence over a period of 40 years.

74. Justification of Project. - The average annual carrying charge is estimated to be $28,020. The average annual benefits which have been evaluated are $41,770. The ratio of evaluated benefits to annual cost is 1.5 to 1. The unevaluated benefits to be derived from the project are public benefits, which are not readily assigned monetary values. The project improves and protects a beach 8850 feet long, of which only 1750 feet, or 20 percent, is adjacent to private property. The 1750 feet of beach fronting private property comprises the northerly end of the section of beach which is to be sanded. Of the total evaluated benefits 89 per cent are derived from the beach to be sanded, 79 per cent being assigned to public interest and 10 per cent to private interest. Benefits to accrue from the entire project are thus almost entirely public benefits and are estimated to be 95 per cent public and 5 per cent private. No benefit has been assigned to the increase in public property values, which increase actually is affected, though it will probably never be realized through the sale of the land. Benefits which have not been evaluated are those accruing to the Town of Nahant, the State of Massachusetts and the United States Government through the protection and maintenance of the Nahant tombolo. The tombolo is entirely publicly owned, having an estimated land value of $600,000, and improvements thereon, com-

prising buildings, roads, and Lynn Harbor shore protection, valued at $405,000. The proposed works will maintain the public investment. The tombolo is the only connection for the entire Town of Nahant with the mainland. The proposed project will prevent inundation of the tombolo by storm waters from Nahant Bay and prevent eventual breaching of the tombolo, both of which conditions isolates the entire town. Isolation of the town involves at all times economic losses to both business and private citizens, and under severe conditions, may involve loss of human life and public welfare. Isolation of the town also isolates principal coast defense positions and thereby involves national security. The proposed project will improve recreational facilities along part of the beach and provide for future improvement of facilities on the balance of the beach. It is concluded that the evaluated and unevaluated public benefits derived from the proposed project are sufficient to justify its construction. The total annual benefits to accrue from the project, evaluated and non-evaluated, are deemed to have a much greater ratio to the annual estimated carrying charges for the work than the evaluated ratio of 1.5 to 1.

75. The proposed plan of improvement will protect public property, and will further provide for the encouragement of the healthful recreation of the people. The shore to be protected is owned by the Metropolitan District Commission of the Commonwealth of Massachusetts. The public interest in the protection and improvement of the beach between Woodbury's Point, Lynn, and Little Nahant, Nahant, has been found to be substantial. The protection and improvement of this publicly-owned beach and property, and the degree of public interest in such work are considered sufficient to warrant the full one-third Federal contribution to the first cost of the plan of improvement as authorized by the general provisions of Public Law 727.

IX. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

76. Coordination With The Cooperating Agency. - The results of the study of Lynn-Nahant Beach, and the recommended improvements have been discussed with the engineering representatives of the cooperating agency. The representatives approved the recommended plan of improvement.

77. The cooperating agency has been advised, and understands that Federal participation in the work will require approval, by the Chief of Engineers, of detailed plans and specifications, and of arrangements for the prosecution of the project prior to commencement of work, and that Federal participation will not relieve local authorities of the requirements set forth in Paragraph 94.

78. The cooperating agency has already accepted the above conditions as applied to the improvement at Winthrop Beach, recommended under the cooperative study, and contained in the report on Winthrop Beach, published in House Document No. 764, 80th Congress, 2nd Session.

79. Discussion. - Lynn-Nahant Beach was developed through disposition of wave transported materials, derived from wave attack on the mainland cliffs, and the former island of Little Nahant. The materials used in this beach-building process were silt, clay, sand, gravel, and larger fragments of stone. Analysis of shore line and offshore changes, indicates that the beach is approaching stability. Samples of surface materials taken at mean tide level, indicate that the surface of the beach is generally fine sand, though considerable stone exists on the backshore in the bathhouse area. The sand, at mean low water elevation, is 3 to 5-1/2 feet deep and overlays clay. Littoral currents, set up by refracted waves entering the bay, transport materials both north and south, from the central part of the beach. The

tombolo tying the island to the mainland has been cut across several times during its geological history.

80. All sources of materials available for beach building have been depleted or cut off from the littoral currents acting along the shore by sea-walls, which have been constructed along the mainland cliff, and around Little Nahant at all points where bed rock is not exposed.

81. The sea-wall along the mainland is a massive curved-face concrete structure, except for a section of rubble stonewall near the southerly end of the beach. This concrete wall, generally built in the period 1904 to 1909, replaced rubble stone walls formerly protecting the area. The wall has been successful in protecting the coastal cliff from damage, though continuous erosion has generally taken place on the beach in front of the wall. The erosion has necessitated the construction of toe walls at most locations to prevent the undermining of the wall. The walls and toe walls, have been subject to continuous wave attack, and have required extensive repairs from time to time as the result of the spalling, cracking, disintegration, and breaking up of concrete surfaces. Areas requiring extensive repairs are presently in evidence at all points along the wall. Consideration of the history of the wall, and the extent of past repairs, and the need of current repairs, leads to the determination that present wall surfaces must be protected from contact with wave action.

82. Consideration of the rate of erosion of the beach north of Woodbury's Point, the use made of the beach for recreational purposes, and its proximity to other developed beaches, leads to the development of a plan of armoring the wall in this area. Prior to armoring, all major cavities and breaks in the concrete are to be filled, and the projections

caused by previous toe wall construction are to be cut off, so that the wall will present a smooth curved face. The sea-wall projections are not strong enough to withstand the energy released by breaking up the waves. The most economical method of armoring the sea-wall has been determined to be the application of a 3-inch coat of reinforced gunite over the entire wall. Where erosion has endangered the stability of the wall, steel sheet pile cut-off walls are to be driven to the elevation of mean low water. Steel sheet piling was selected for cut-off walls because it may be driven to depths at which there is no future danger of the wall being undermined. The analysis of the rates of erosion at the base of the sea-wall indicates that after the steel sheet pile cut-off walls are driven, and at the present rate of erosion, it will require 39 years before the beach elevation will reach the base of the highest of the existing concrete toe walls. In view of the slow rate of erosion at the base of the wall, and the degree of protection afforded the cliff by the wall, it is to be expected that the plan of armoring and stabilizing the sea-wall will result in its continued successful operation for a substantial period of time. However, local authorities should frequently check the stability of the wall in relation to superimposed loads and beach elevations. If in the future, sections of the wall are found at any time to be endangered, heavy riprap may be required in front of the endangered sections at the sacrifice of beach areas.

83. The method to be employed for the protection of the walls south of Woodbury's Point is subject to the development of the plan of improvement for the bathing beach area. The situation of the bathing beach is one in which the backshore is too stony to provide a satisfactory

recreational beach, and is so low that it is subject to storm wave attack, allowing adjacent low areas to be flooded. The stones appear through the reworking of beach materials. There is no shore protective structure in the area. Consideration of the factors affecting the area leads to the development of a plant of improvement wherein artificial sand fill is placed to bury the stones, to raise elevations so that the backshore elevation is equal to that of the top of sea-wall north of the bathing area, and the mean high water line is 150 feet seaward of a line connecting the northerly sea-wall and the sand dunes southerly of the area. This plan will result in adequate protection for the low lands with the wide beach serving as a dissipator for wave energy prior to the waves reaching the extending sea-wall line. The wide beach will provide an added recreational area. The fill is designed to have the same slopes as the stable beach along the tombolo, and to realign the shore line as a continuation of the sweeping curve forming the tombolo shore line. In order to accomplish proper placement of artificial fill, it must be extended northerly, in front of the sea-walls, to Woodbury's Point. The fill will thus arrest the erosion in front of the sea-walls, and protect the walls from wave attack. The faces of the walls are practically buried by the fill, since the top elevation of the fill to prevent wave attack on adjacent land areas was established as that of the rubble masonry walls. The burying of these walls will eliminate all need of repairing the same, and is particularly desirable in front of the rubble wall since it has been subject to destruction under wave attack.

84. In so far as it can be determined there is no source of material from which the beach can be naturally replenished, and materials suitable for artificial fill are not available within reasonable distances for hydraulic dredging, hence the material must be brought in from other areas. In view of the stability of the beach and its relatively slow rate of erosion, it is not considered that the construction of groins is necessary to maintain the fill. The placement of the fill on designed slopes and grades will result in a beach which, with proper maintenance and periodic replenishment of artificial fill, will provide adequate protection to the coast and existing seawalls, bury undesirable stones, arrest erosion, and provide a recreational area of dry beach twice as great as that now existing at high tide.

85. The situation along the Nahant tombolo is that of a low, narrow strip of land separating two bodies of water, the land being stable as long as it is not breached. The breaching of the tombolo is prevented by a low sand dune which is adjacent to the back shore of the ocean-side beach. In recent years as much as 20 feet of the seaward face of the dune was lost in one storm. If the sand dunes were breached, storm waves would deplete the ocean beach and carry the material into Lynn Harbor. The breaching of the tombolo would also result in the breaching of the Nahant Road which is the only link between the Town of Nahant and the mainland, thereby isolating the Town and major segments of the military coastal defense positions which are located within the Town.

86. For the protection of the tombolo the plan of improvement provides for the construction of a free standing stone mound. The mound would be constructed from readily available rock; its

flexibility makes it adaptable to foundation conditions and if subsequent settlement or partial breaching should occur, it can be readily restored to grade.

87. The total cost of the proposed plan of armoring the sea-walls between Blaney Rock and Woodbury's Point (Profile 1 to 16 Area) is estimated to be $138,000. This work is found to be maintenance, required to repair and stabilize the wall to insure its continued successful protection of the coast. The provisions of Public Law 727, which law provides for Federal participation in the cost of construction of shore protective works, are very explicit in stating that the Federal Government will not participate in the maintenance of protective structures. The special provision of Public Law 727 provides for Federal participation in the repair of existing walls where the walls protect "a public highway considered by the Chief of Engineers sufficiently important to justify protection". Lynn Shore Drive adjacent to the seawall, is a localized parkway which cannot be deemed important to the welfare of the general public. Numerous side streets are available to connect to others areas of Lynn and Swampscott. A principal State highway route parallels the drive about 0.2 miles landward. The loss of the shore drive would not endanger the general public nor disrupt free flow of traffic in the community. Traffic disruption would be limited to those having business at residences on the drive. Federal participation in the plan of maintenance is therefore not in accordance with the policy set forth under existing law. The accomplishment of the recommended work would thus become the responsibility of local interests.

88. The estimated cost of the proposed plan of improvement of the beach between Woodbury's Point and the dunes on Little Nahant (Profile 12 - 16 Area) is $366,000, and of protection of Nahant Beach (Profile 16 - 20 Area) is $98,000, making a total of $464,000 for these two items. The shore to be protected, Profiles 12 - 20, is owned by the Metropolitan District Commission of the Commonwealth of Massachusetts. The public interest in the protection and improvement of the beach has been found to be substantial. It is considered that the protection and improvement of the publicly owned beach and the degree of public interest therein is sufficient to warrant the full one-third Federal contribution toward the first cost of the proposed plan, as permitted by the general provisions of Public Law 727. The estimated amount of the Federal contribution is $154,670.

89. The annual cost of the proposed plan of protection and improvement of the shore between Woodbury's Point and Little Nahant (Profiles 12 - 20) is estimated at $28,020. Partially evaluated benefits to be derived therefrom amount to $41,770. The ratio of partially evaluated annual benefits to annual costs is 1.5 to 1. Other benefits are discussed in Paragraphs 69 and 72 for which no monetary evaluation has been made. The total benefits, evaluated and unevaluated, are found to be of sufficient value to justify the cost of the project. These benefits include recreational benefits, maintenance and protection of existing public investments, the security of the general public welfare of the Town of Nahant through stabilization of the tombolo including prevention of economic losses and protection of human life, and the insurance of free access to major defense positions in the interest of National security. The benefits to be realized from the

project are almost entirely of a non-Federal public nature. Public benefits are estimated to be 95% of the total benefits. It is therefore concluded that ratio of total benefits, evaluated and unevaluated, to the annual cost of the project greatly exceed the evaluated ratio of 1.5 to 1.

90. Conclusions.- The Division Engineer concludes that the best plan for the prevention of further erosion and for stabilizing and improving the beach and protecting the seawalls and other public property at Lynn-Nahant Beach should provide for: (See Plate A-6)

a. The repair and stabilization of the existing concrete sea-wall between Blaney Rock and Woodbury's Point.

b. The improvement of the beach with an artificial supply of sand between Woodbury's Point and the dune on Nahant tombolo and the construction of a stone mound along the tombolo between the improved beach and Little Nahant.

The Division Engineer concludes that the construction of the above-described work is warranted.

91. That part of the proposed protective works involving repairs to the existing walls between Blaney Rock and Woodbury's Point, is in the nature of maintenance work, and as such is not eligible for participation by the United States. The balance of the proposed work, which includes artificially building up the beach and constructing the stone mound, is new construction and is primarily for the protection of publicly owned shores and therefore meets the requirements for Federal participation in the first cost of construction of works for the improvement and protection of the shore. The nature and amount of

public benefits are considered to be sufficient to warrant the maximum one-third participation by the United States in the first cost of the proposed new construction, as permitted by Public Law No. 727, 79th Congress, 2nd Session.

92. Recommendations. - It is recommended that the Commonwealth of Massachusetts adopt a project for the protection and improvement of Lynn-Nahant Beach to the extent of

a. Constructing steel steet pile cut-off walls between Blaney Rock and Woodbury's Point at those places where toe walls do not extend below elevation 6.0 feet above mean low water, and providing an armor of 3-inch thick, steel reinforced gunite on the existing concrete wall in the same section, all at an estimated initial cost of $138,000, the entire amount of which is to be borne by the local agencies.

b. Improving the beach between Woodbury's Point and the dune on Nahant tombolo, a distance of about 2,600 feet, by placing approximately 172,000 cubic yards of sand thereon, to provide a backshore elevation of 18.0 feet above mean low water, and constructing a stone mound having a top elevation of 18.0 feet above mean low water along the tombolo from the improved beach to Little Nahant, a distance of 6,250 feet, all at an estimated initial cost of $464,000 and $6,840 annually for maintenance.

93. It is recommended that the United States adopt a project for the protection and improvement of the shore between Woodbury's Point and Little Nahant by authorizing participation through the contribution of Federal funds in an amount equal to one-third of the first cost of construction of the project. The project consists of the work described in Subparagraph 92-b and its cost to the United

States is estimated to be $154,670. Contribution of Federal funds shall be made contingent upon approval by the Chief of Engineers of the detailed construction plans and specifications and the arrangements for the prosecution of the new work prior to its commencement.

94. It is further recommended that the contribution of Federal funds shall be also contingent upon agreement with the Commonwealth of Massachusetts providing that the Commonwealth will

a. Maintain and repair the works as may be required to serve the intended purpose, including periodic replenishment of the artificial fill on the beach.

b. Provide free of cost to the United States, all lands, easements, and rights-of-way necessary for the initial work and subsequent maintenance.

c. Hold and save the United States free from claims for damages connected with or resulting from the work.

JAMES H. STRATTON
Colonel, Corps of Engineers
Division Engineer

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LYNN-NAHANT BEACH

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APPENDIX I

EXISTING PROTECTIVE STRUCTURES AT LYNN-NAHANT BEACH

1. General. - The coast line of King's Beach Reservation and Lynn Shore Reservation is protected by a continuous concrete and masonry sea-wall. The seaward base of the sand dune on Nahant Beach Parkway is partially protected with riprap. This appendix describes the shore and the protective structures so as to present a concise picture of protective structures and their relation to beach condition. The location and sections of the several structures are indicated on Plate A-1. Pictures of selected structures are shown in Figures A-1, A-2 and A-3. Elevations of the top of sea-walls as given herein were determined from the Boston District survey of 1945-46 wherever possible. Other elevations were determined from construction drawings.

2. Private Walls, Blaney Rock Area. - Blaney Rock is the headland marking the northerly limit of the study area. Between the extremity of the headland and the Metropolitan District Commission sea-wall, the base of the cliff is protected by a series of rubble masonry walls. The tops of these walls are generally about 20 feet above beach elevation. The walls are built to this height to retain fill used to enlarge house lots. One wall is only about 5 feet high and serves as the foundation for a wooden shed, neither of which evidences any signs of damage from waves. The walls have been constructed for a considerable number of years, their location being indicated on a plan dated 1904. The shore fronting these walls is of exposed ledge at the extremity of the headland, and hard-packed sand and boulders westward of the ledge.

3. Metropolian District Commission Sea-Wall, Profiles 1 to 8 Area (See Figures A-1 and A-3). - The sea-wall between Blaney Rock, adjacent to Profile 1, and Red Rock, adjacent to Profile 8, was con-

structed by the Metropolitan District Commission in 1904. Prior to this date, the shore was protected by various privately-owned wood and masonry walls and bulkheads. These structures were located generally 50 to 80 feet behind the high water line. The sea-wall was constructed as a concrete gravity wall having a top width of 2 feet, 9-5/8 inches. The wall was capped with a concrete coping 3½ feet wide and 22-1/4 inches thick, which projected 5-1/8 inches in front of the wall. The coping was not anchored by dowels, but was secured in place with a dovetail key. The face of the wall was curved to about elevation 11.5 feet above mean low water, the curve having a radius of 15 feet. Below the curved portion, the face was vertical to the base of the wall. The back of the wall had a batter of 1-1/2 inches to 12 inches. The exposed surfaces were provided with temperature steel. The top and bottom elevations of the wall varied with the location along the beach since the wall was located in an area between two high points of land. The elevation of the top at the north end of the wall was 28.6 feet above mean low water. The lowest top elevation of the wall was adjacent to Profile 3 and was 17.3 feet above mean low water. The elevation of the south end of the wall was 22.5 feet above mean low water. The elevation of the base of the wall varied from 4.4 feet above mean low water to 9.6 feet above mean low water, being generally at an elevation of 7.6. The wall was generally founded on clay and gravel. Between about Profile 3 and the midpoint between Profile 1 and 2, the wall was founded on a double row of wood piles whose top elevations varied from 6.0 feet above mean low water to 10.0 feet above mean low water. The beach elevation at the line of the wall near Profile 1 was 10 feet above mean low water, near Profile 2 was about 11 feet above mean low water, near Profile 5 was about 17 feet above mean low water, and near Profile 8 was about 11 feet above mean low water. The space behind the wall was backfilled with earth materials. Near the clay line, a longitudinal 8-inch underdrain was installed behind the wall. This underdrain was intercepted by 10-inch and 12-inch outlets which drained adjacent highway catch basins. The outlets passed through the wall below the sand line and entered rock-filled blind drains, 25 feet by 4 feet by 4 feet in dimension, buried 3 feet 6 inches below the beach surface about 8 feet seaward of the wall.

4. Eight bastions were provided along the wall for access to the beach. These bastions projected 6 feet in front of the sea-wall, and except at Profile 3 were provided with two sets of stairs which followed the curve in the face of the sea-wall. The bastion at Profile 3 was provided with ramps in lieu of steps. The bastion between Profiles 3 and 4 also serves as the outlet for a large box culvert.

5. The sea-wall and bastions have been subject to considerable damage since their construction. The face of the wall has cracked and disintegrated, leaving large holes in the concrete. The toe of the wall has been broken and in many places undermined. The bastion steps have been repeatedly broken up. Much of the repairs to these structures has been accomplished by maintenance forces as the damage occurred. Extensive repairs to this wall were commenced in 1933 and have been in progress periodically since that time. In 1945, steps to two bastions were repaired, one bastion was reconstructed and 355 feet of toe wall was constructed. The toe wall extended to about elevation 0.0. This periodic work has included the reconstruction of bastion steps and their partial replacement with ramps, the replacement of broken wall cornices, the patching of holes in the face of walls and the installation of concrete footings and toe walls. The construction of toe walls and footings has been necessary to prevent undermining of the wall south of Profile 4. Footings have been extended to depths varying up to 7 feet

below the original base of the wall. The blind drains have been almost entirely removed from the beach, there being only four such drains left. Wave action broke the outlet pipes and plugged them up as erosion exposed the blind drains. Settlement broke the pipes off behind the wall. These pipes have been sealed off and new outlets for the catch basins have been broken through the wall four feet below its top.

6. The beach fronting the wall is hard-packed sand in both backshore and foreshore areas except in the area of Profile 3 where there is soft sand in the backshore area. A small amount of stone always piles against the wall in the area of Profile 4. There has been a progressive general lowering of beach elevations along this wall except at Profile 3. In addition to this general progressive erosion, a seasonal change of beach elevation is affected along the beach, with the sand covering the base of the wall in summer and exposing it in winter. Severe storms pile stones against the wall, one such storm on November 28-30, 1945, being observed to have piled stones against the wall to the extent of raising the beach elevation 2 to 3 feet, and half closing the box culvert.

7. The wall at present is in poor condition with its face cracked and spalled, the toe walls damaged and the bastion steps broken. This condition exists at all points along the wall but is particularly bad in the Profile 6 to 8 area where the greatest damage has been experienced through the life of the structure.

8. Metropolitan District Commission Sea-Wall in Red Rock Area (Profile 9)(See Figure A-1). - Prior to the development of the public reservation, the Red Rock area was protected by a rubble masonry wall which stood generally along the back of the present concrete wall. The Metropolitan District Commission erected the present wall between 1904 and 1909. This wall was constructed in accordance with the general details

used for the wall north of the Red Rock area except that the coping was cast integral with the wall. The top elevation of the wall was 22.5 feet above mean low water. The wall was generally founded on ledge rock which was near or above beach elevations. At the outer end of the headland, the base of the wall is on ledge at elevation 16.8. At the inner end of the headland where the wall was founded on beach materials, the bottom elevation was 4.6 feet above mean low water. The line of the wall was generally located so that the existing rubble wall was utilized as backing for the new concrete wall, with a resultant reduction in the thickness of the concrete wall. Where the new wall was located forward of the existing wall, earth backfill was used between the walls and blind drains were extended through the wall to the beach. A wood groin was extended 400 feet northeast from the east side of Red Rock at a point about 200 feet from the mainland. By 1925, this groin had been generally destroyed. The wall has been subject to continued damage from wave action, becoming cracked and spalled. In 1933, a concrete toe was constructed along the east and west sides of the area to reinforce the toe of the original wall. This toe wall has been severly damaged. In 1945, 165 feet of the toe wall on the easterly side of the area was replaced. The new toe wall extends to the elevation of mean low water. The greatest damage to the wall is concentrated on the east side of the area at its junction with the mainland wall. The beach fronting Red Rock is generally stony with some boulders, the outer end of the headland is exposed ledge.

9. Metropolitan District Commission Sea-Walls at Woodbury's Point (Profiles 10 - 12)(See Figure A-1). - Prior to the original work in this area by the Commission, the area was protected by masonry walls which stood just behind the present alignment of the wall. The tops

of the masonry walls were from 0 to 4 feet below the top of the present wall. Between Red Rock and the site of the present tower bastion there was a walk along the top of the wall. Between the site of the present tower bastion and the extremity of Woodbury's Point, the cliff above the masonry wall was protected by riprap paving laid on a slope of 1 on 2 to elevation 26.6 feet above mean low water. Above this riprap paving there was a secondary masonry wall with a top elevation of 32.6 feet above mean low water. In 1907 the Commission constructed the present tower bastion and extended the concrete wall from the west side of Red Rock to the bastion. The section of the new concrete wall was similar to that of the wall north of Red Rock except that a toe wall, 4 to 5 feet deep, was provided under the sea-wall when not founded on ledge; a curve was introduced between the vertical face of the toe wall and the concave face of the sea-wall proper and the coping was cast separately from the wall but doweled to the wall. The top of the wall was at elevation 22.6 feet above mean low water and the bottom of the wall was between elevation 5.2 and 6.6 feet above mean low water. The section of the wall was modified at the base of Red Rock to utilize the existing rubble wall as a backing. Earth fill was placed behind the wall and a 12-foot wide walk was provided along the top. The existing riprap paving was not disturbed except for the construction of the tower bastion which in part utilized the existing wall as a foundation. The top of the bastion was at elevation 32.6 feet above mean low water. In 1931, the concrete wall was extended from the tower bastion around the extremity of Woodbury's Point to the mainland. This wall was of the same section as the other concrete walls but did not have a toe wall. At this time there was a large washout in the wall and riprap pavement near the end of Woodbury's Point. The existing rubble sea-wall was left in place as backing, where it had not been demolished. The riprap paving above it was removed and the rubble wall above paving was replaced with a concrete wall. The top elevation of the concrete sea-wall was 22.6 feet above mean low water. Earth fill was placed behind the wall and a 9-foot wide walk was constructed along the top of the wall. A sloped seeded area was provided between the walk and the upper concrete wall. The top of the upper concrete wall was at elevation 32.6 feet above mean low water. The base of the wall southwest of the tower bastion is protected by riprap and wood piles, the piling being the remains of an old wood pile breakwater. In this area the wall has been badly damaged, with construction joints being opened, the face of the wall being worn away to expose the reinforcing steel, and the coping broken. The base of the wall northeast of the tower has been similarly damaged and a concrete toe has been constructed along the base of the wall, extending almost to Red Rock. This toe is badly worn and the reinforcing steel is generally exposed.

10. The beach between Red Rock and the bastion is of hard-packed gravelly sand with a deposit of shingle at the base of the wall. The wave action continually works the material against the face of the wall. The beach southwest of the bastion is of coarse sand, stones and boulders. The wall is subject to wave action that tosses spray onto the walk above the wall even when the waves are moderately high. On November 8, 1945, at high tide a 6-inch chop breaking at the base of the wall was observed to toss spray onto the walk.

11. Metropolitan District Commission Sea-Walls Between Woodbury's Point and the Lynn-Nahant Line (Profiles 12 to 15) (See Figure A-3). - Prior to 1907, the areas between Woodbury's Point and the Lynn-Nahant Town line, were protected by rubble masonry walls. In 1907, the Commission erected a concrete sea-wall between Woodbury's Point and Nahant

Street (adjacent to Profile 14). This wall was located generally about 10 feet seaward of the rubble walls. This wall was of the same section as the one constructed between Red Rock and the tower bastion. The elevation of the top of this wall varied from 22.0 feet above mean low water at Woodbury's Point to 18.6 feet above mean low water at Nahant Street. Blind drains were passed through the wall and out onto the beach as in the area north of Red Rock. A bastion was constructed at the foot of Wave Street and a reinforced concrete ramp was constructed at the foot of Nahant Street. The ramp was 80 feet long, 20 feet wide and consisted of two parallel concrete walls supporting a concrete deck slab. This section of the concrete wall has been subject to continued damage. By 1934, the concrete ramp was damaged to such an extent that it was removed and the wall filled in across its base. In 1941, extensive repairs were accomplished, with the wall being patched, the bastion steps being repaired, and a new concrete toe wall, 4 feet thick and 4 to 6 feet deep, being constructed. Riprap was placed in front of the tow wall. Holes in the walk behind the wall were also repaired. The beach fronting this wall is generally stony.

12. The rubble wall between Nahant Street and the Lynn-Nahant town line has never been replaced by the Commission. It has been repaired from time to time with the steps at the bastion being repaired in 1941, and the entire bastion being rebuilt in 1945. A toe wall has been constructed along this wall. When the wall has been repaired the blocks of stone have been set in mortar. The wall has been backed with concrete adjacent to the rebuilt bastion. The top of the wall is at elevation 18.6 feet above mean low water. The beach elevation adjacent to the wall just south of the bastion rises to a point about 12 inches below the top of the wall. The southerly end of the masonry wall turns west at the Nahant-Lynn town line and is tied to the coastal

cliff about 80 feet from the sea-wall face of the wall. This end of the wall is the southerly limit of sea-walls on the Lynn-Nahant Beach.

13. Shore Protection on Nahant Beach Parkway. - The Nahant tombolo was unprotected along the seaward face prior to 1935. There were miscellaneous walls, bulkheads, and riprap along the Lynn Harbor side of tombolo. In 1935, riprap was placed along the seaward toe of the sand dune for approximately 4700 feet along the north end of the tombolo, with the northerly end of the riprap being adjacent to the southerly limit of the bathhouse area. The riprap consists of stones, varying up to a cubic yard in size laid in a continuous belt 10 feet wide. This riprap has not been dislodged since it was placed and has stabilized the toe of the sand dune. It was noted that the severe storm of November 28-30, 1945, caused the toe of the unprotected section of the dune to retrograde for distances varying up to 20 feet while the riprap maintained the toe of the protected section. The high waters of the storm, however, washed over the top of the riprap eroding the dune above the riprap. The top of the dune had been generally regarded as stable. In 1906, a bridle path was constructed along the top of the dune and subsequently the path was paved with bituminous material. The November 1945 storm practially destroyed the path.

14. The beach fronting the riprap is a relatively flat beach of hard-packed sand. The backshore area of the northerly half of the tombolo is generally overlaid with stone varying from 1/2 to 1 inch in size, with some stone up to 3 inches in size. The stones form typical cusps. There is soft sand immediately adjacent to the riprap. There is no stone on the backshore areas south of the riprap.

15. The original development of the Lynn Harbor side of the tombolo consisted of an electric car line adjacent to the harbor and a highway (Nahant Road) between the car line and the sand dunes. Miscel-

laneous riprap, rubble walls, and bulkheads protected the harbor side of the car line. The Metropolitan District Commission subsequently acquired the road bed of the car line for use as a parking area. The shore protection was inadequate in height and strength to resist the storm waves in Lynn Harbor, with the result that the parking area and road were flooded and sections of the structures and parking area were washed out at numerous times. This entire area was reconstructed in 1947, with the road being located adjacent to the harbor, the parking area being located between the road and sand dunes to provide better access to the ocean beach, and the shore protection being reconstructed. The harbor side of the highway is now protected by riprap between a point opposite the bathhouse and a point about 4800 feet south. The riprap has a top elevation of 15 feet above mean low water. Between the riprap and Wilson Road, two sections of new wall have been built so as to form, with the previously existing stone wall, a continuous wall about 2300 feet long. Top elevations of the new wall sections are between 18 and 22 feet above mean low water. The wall was constructed by grouting existing ballast as a foundation, building a stone-faced, concrete wall to highway elevation, and placing a 3-foot high stone coping above the wall. This reconstructed shore protection will reduce damage previously experienced by the road and parking area, but flooding will not be eliminated because of the low elevation of the riprap.

16. Shore Protection Along Little Nahant. - The base of Little Nahant is protected by a series of rubble and concrete walls which extend from the tombolo to the outcropping ledge at the outer end of the headland. These walls were constructed prior to 1920, and originally protected a road skirting the headland's base. Today they protect a series of waterfront cottages and in part support the cottages. The walls have not suffered great damage, though two of them require rebuilding. One other wall

collapsed because the owner removed boulders from the shore to make a bathing beach. The beach fronting the walls is flat, hard-packed sand with numerous large boulders. The beach is building up in some sections.

APPENDIX II

COMPOSITION OF LYNN-NAHANT BEACH

1. General. - The present composition of Lynn-Nahant Beach may be summarized as follows:

a. King's Beach. Profiles 1-3. - Smooth, hard-packed sand.

b. Lynn Beach. Profiles 4-8. - Hard, smooth sand with some stone deposit at base of wall.

c. Lynn Beach. Profile 9. - Stony with ledge outcrop at outer end of Red Rock.

d. Lynn Beach. Profiles 10-11. - Hard gravelly sand with some stone.

e. Lynn Beach. Profiles 12-14. - Hard sand with some stones and a few boulders.

f. Nahant Beach. Profiles 15 - 16. - Hard sand on foreshore. Soft sand and a great amount of stone on backshore.

g. Nahant Beach. Profile 17. - Hard sand beach with stony backshore. Sand dune above extreme high water elevation.

h. Nahant Beach. Profiles 18-20. - Hard-packed sand, with a sand dune in the area of Profile 18. Shingle and stone deposit on the backshore in area of Profiles 19 and 20.

i. Little Nahant. Profiles 21-24. - The beach near Profile 21 is hard-packed sand on the foreshore, and stony and boulder strewn on the backshore. The outer end of Little Nahant, Profiles 22 - 24 is a jagged ledge outcrop.

2. Typical Beach Conditions. - Typical beach conditions are shown on Figures 1 to 3 and are described in the following notes which were made on November 8, 1945.

a. Profiles 1-2 Area. -The beach is smooth, hard sand with considerable weed over it. At about the 3/4 tide level there is a film of ground shells. Some pebbles with kelp attached to them were observed. The beach is entirely under water at high tide.

b. Profile 3 Area. - The backshore is building up with soft sand. There is a berm at about mean high water. The discharge from the culvert, at about the midpoint between Profiles 3 and 4, cuts a channel 4-6 inches deep across the hard beach. This channel has definitely defined vertical sides.

c. Profile 4 Area. - The beach is hard, smooth sand, and is very flat. A deposit of stone lies at the base of the wall. The Metropolitan District Commission Police state that these stones remain in place all year.

d. Profile 6 Area. - The beach is hard, smooth sand and is very flat.

e. Profile 8 Area. - The beach is generally flat and of hard firm sand.

f. Profile 9 Area. - The beach around Red Rock is stony and the outer end of the wall rests on a ledge outcrop.

g. Profile 10 Area. - The beach in this area is of hard gravelly sand with a deposit of shingle at the base of the wall.

h. Profile 12 Area. - The beach is hard sand and of a very flat slope from Profile 12 to Profile 18. Riprap has been placed against the wall from Woodbury's Point to the first steps south of the point. The southerly end of the riprap has become buried in the sand. There are a few boulders on the beach.

i. Profiles 13-14 Area. - The beach is flat and of hard sand. At Profile 14, the bastion and a section of the rubble wall are being rebuilt. Excavation for this work showed the beach material to be generally sand with some clay and a lot of boulders. A limited area of peat, one-foot thick, was found at a depth of 3 feet below the beach level.

j. Profiles 14-15 Area. - The backshore beach is stony but the beach is firm to walk on.

k. Profile 16 Area. - The foreshore area is firm hard-packed sand. Cusps of small stone are forming near high water level. The backshore area is stony with stones taking a cuspate formation. The stones have been graded into small pockets of various sizes, varying from fine material which is practically coarse sand to one inch stone. There are some 2-inch to 3-inch stone in the area. The pockets vary in depth, being over 12 inches deep in the center of the cusps. The extreme backshore area is of soft clayey sand which contains some 3-inch stone. South of this area there is a low sand dune in back of the coast line.

l. Profile 17 Area. - The beach in this area is steeper than it is farther south. It is of firm sand but contains so many small stones, 1/2 to 1-inch in size, that it is almost a stony beach. The stone deposit is most dense at 3/4 tide level and thins out above high water level. The backshore area fronting the dune is of soft sand.

m. Profiles 18-19 Area. - The beach is hard, firm sand and has a gradual slope. There are ripples impressed into the sand.

n. Profile 20 Area. - (1) Along the tombolo, the foreshore beach is hard-packed sand. The backshore area is covered with small stones and shingle. The stone and shingle deposit extends to almost Profile 19. There is no dune in back of the beach, the area being used for the parking of automobiles.

(2) Along the base of Little Nahant, the beach is flat and of hard-packed sand with numerous large boulders.

o. Profile 21 Area. - The beach between Profiles 20 and 21 is about the same as described for Profile 20.

p. Profiles 22-24 Area. - The outer end of Little Nahant is a steep jagged ledge outcrop, full of cracks and fissures.

3. Changes Due to Heavy Storms. - Changes in beach composition are affected by heavy storms, the extent of such changes being indicated by the following observations made December 3, 1945, after the 3-day northeast storm of November 28-30, 1945.

a. Profile 1 — 3 Area. - The beach appears to be about the same as it was prior to the storm, being of hard sand. Starting at a point between Profiles 2 and 3, stones have been piled up against the base of the sea-wall and over the beach for about 20 feet in front of the wall.

b. Profile 4 Area. - Small stones and sand have been piled up against the sea-wall to raise the beach elevation at the wall for heights varying up to 4 feet. This material extends seaward about 20 feet and has a steep slope. The stones filled in the lower half of the culvert.

c. Profile 5-6 Area. - The beach in this area has been raised about 2 feet along the base of the sea-wall by a deposit of loosely packed small pebbles. The deposit extends about 15 feet seaward.

d. Profile 7-8 Area. - The beach has been built up and has become stony.

e. Profile 9 Area. - There was no apparent change in beach conditions around Red Rock.

f. Profile 11 Area. - There was no apparent change in beach condition.

g. Profile 14 Area. - Material excavated in construction of the new ramp and placed on the beach was washed away. This material was above the top of the toe wall.

h. Profiles 15-16 Area. - The beach was generally built up in this area. At the end of the rubble wall the elevation of the beach was raised about six inches. Around the playground, the elevation was raised about twelve inches.

i. Profiles 16-18 Area. - (1) At the northerly end of the Nahant tombolo, the dune has been, in places, cut back to the bridle path. A large boat was washed onto the top of the sand dune. About six inches of sand was washed over the road.

(2) In the central section of the tombolo, the beach elevations were lowered about 18 inches at the base of the eroded sand dune. Boats were washed over the top of the dune. The paved bridle path was partially destroyed.

(3) The toe of the dune was generally cut back from 10 to 20 feet leaving the picnic fireplaces out on the beach,whereas,they previously were at the base of the dune.

j. Profiles 19-20 Area. - There did not appear to be any changes in this area.

k. Profiles 21-24 Area. - This area did not appear to have experienced any damage.

APPENDIX III

COST ESTIMATES FOR LYNN-NAHANT BEACH

I. ESTIMATED FIRST COSTS

1. Repair of Concrete Sea-walls, Profiles 1 - 12. - Constructing 1690 feet of steel sheet pile cut-off wall between Profiles 6 and 8 and around Woodbury's Point, filling voids in wall and building up steps and ramps, and armoring entire wall with gunite.

Cutoff Walls - 195 Tons, Steel Sheet Piling @ $109.00	$ 21,255
Filling Voids, Building up Structure - 3800 cubic feet @ $6.00	22,800
Armoring wall with Gunite - 75,800 square feet @ $1.00	75,800
	$119,855
Engineering and Contingencies	18,145
	$138,000

2. Improvement of Beach, Profiles 12-16 Area. - Placement of sand fill.

Sand fill, 172,000 cubic yards @ $1.85	$318,200
Engineering and Contingencies	47,800
	$366,000

3. Protection of Nahant Beach. - Construction of 6250 linear feet of stone mound.

a. Earthwork, excavation and backfill, 6000 cubic yards @ $.50	$ 3,000
b. Stone core, 12,220 Tons @ $3.75	45,825
c. Stone shell, 6630 Tons @ $4.50	29,835
d. Stone steps, 230 Tons @ $20.00	4,600
e. Rehandle existing riprap, 2400 Tons @ $1.00	2,400
	$ 85,660
Engineering and Contingencies	12,340
	$ 98,000

II. ESTIMATED ANNUAL CARRYING CHARGES

1. Allocation of Costs. - The plans for the improvement of the beach between Profiles 12 and 16 and the protection of Nahant Beach qualify under the provisions of Public Law 727 for Federal participation to the extent of one-third of the first cost of each plan. The first costs of these two plans are, therefore, allocated as follows:

Improvement of Beach, Profiles 12-16	$366,000
Protection of Nahant Beach......................	98,000
Total First Cost................................	$464,000
Federal Cost....................................	$154,670
Non-Federal Cost................................	309,330
Total First Cost................................	$464,000

2. Federal Annual Carrying Charge.

a.	Interest 3% of $154,670.....................	$ 4,640
b.	Amortization, estimated period 40 years ($154,670) (.01326)..........................	2,050
c.	Maintenance	0
d.	Total Federal Carrying Charge...............	$ 6,690

3. Non-Federal Annual Carrying Charge.	
a. Interest, 3-1/2% of $309,330	$ 10,830
b. Amortization - 40-year period ($309,330)(.01183)	3,660
c. Estimated Annual Maintenance *	6,840
d. Total Non-Federal Carrying Charges	$ 21,330
4. Total Annual Carrying Charge.	$ 28,020

*Based upon estimated quantities required to maintain sand fill and stone mound at design slopes and grades. The estimate of the quantity of sand replenishment is based upon the area involved and the rates of erosion adjacent to the area.

Sand Fill, 3000 cubic yards @ $1.85	$ 5,550
Stone moved	400
Total Construction Cost	$ 5,950
Engineering and Contingencies	890
Total Cost	$ 6,840

APPENDIX IV

ANNUAL BENEFITS FOR LYNN-NAHANT BEACH

(Benefits for work recommended between Profiles 12 and 20)

1. Average Annual Direct Damages Prevented. - Based on records of expenditures and analysis of beach changes, the direct damages prevented are:

a. Federal	$ 0
b. Non-Federal Public	
(1) Storm Damage Repair	
(a) Profiles 12 to 15	
Metropolitan District Commission	4,000
City of Lynn	0
(b) Profiles 15 to 20	
Metropolitan District Commission	4,300
Town of Nahant	200
(2)* Loss of beach, Profiles 12 to 15	
3000 c.y. at $1.85	5,550
c. Private	0
Total direct damages prevented	$14,050

*Estimated annual loss on beach area to be sanded, based upon studies of rates of erosion in adjacent areas.

2. Recreational Benefits. - a. The proposed rehabilitation of the beach between Woodbury's Point and the dunes along the tombolo, Profile 12-16 area, will create a dry sandy beach 2600 feet long and 150 feet wide at high tide. The existing stony beach consists of approximately one-half of this area, that beach being generally south of Profile 14. Data on patronage in this specific area is not available, but it is estimated that due to present stony conditions, the beach is utilized only to fifty percent of its capacity. Allowing the desirable area of

75 square feet per person, the proposed beach has a total capacity of 5,200 patrons, with the capacity of 3,900 patrons being due to increased beach area and improved conditions at existing beach. The possible annual increased attendance during the 10 week summer period, allowing 25 percent for inclement weather, becomes 205,000 people. In localities where a fee is charged for the use of the beach, the non-federal public benefits can be evaluated in terms of additional revenue to be realized from the improvement. Though the policy of the State of Massachusetts is not to make such charges, the same benefits exist and may be evaluated. The nominal minimum fee charged for beach usage is 10 cents per person. The annual benefit thus in terms of increased patronage and nominal usage fee becomes

205,000 x $.10 = $20,500

b. The proposed rehabilitation of the beach will result in increased valuations to private properties adjacent thereto. Private property adjacent to the proposed improvement lies between Woodbury's Point and Washington Street at the Lynn-Nahant line. This area is almost entirely year-round residential, containing a large apartment hotel, apartment houses and many large homes. The assessed valuation of the property in Lynn adjacent to the shore is given in Paragraph 70 of the report. This valuation covers land between Swampscott and Nahant, a distance of 5,550 feet. The proposed improvement affects property for a distance of 1750 feet along the shore. The affected valuations thus become

$$\text{Frontal Property } \frac{1750}{5550} \times 1{,}259{,}000 = \$397{,}000.$$

$$\text{Marginal Property } \frac{1750}{5550} \times 6{,}379{,}000 = 2{,}011{,}000.$$

$$\text{Total} \quad \overline{\$2{,}408{,}000}.$$

The improved beach provides for a greater earning power of this property during summer months through actual or possible increased rental returns due to the greater attraction of the beach. It is estimated that rental increases of 10 percent can be expected during the summer months, which is equivalent to a 2.5 percent increase in annual rental. This total annual benefit, assuming rental to be 12 percent of the assessed value, is

$2,408,000 x .12 x .025 = $7,220.

The increased tax return from the property would be, at the 1948 rate of $45.60 per $1000

$2,408,000 x .025 x .0456 = $2,750.

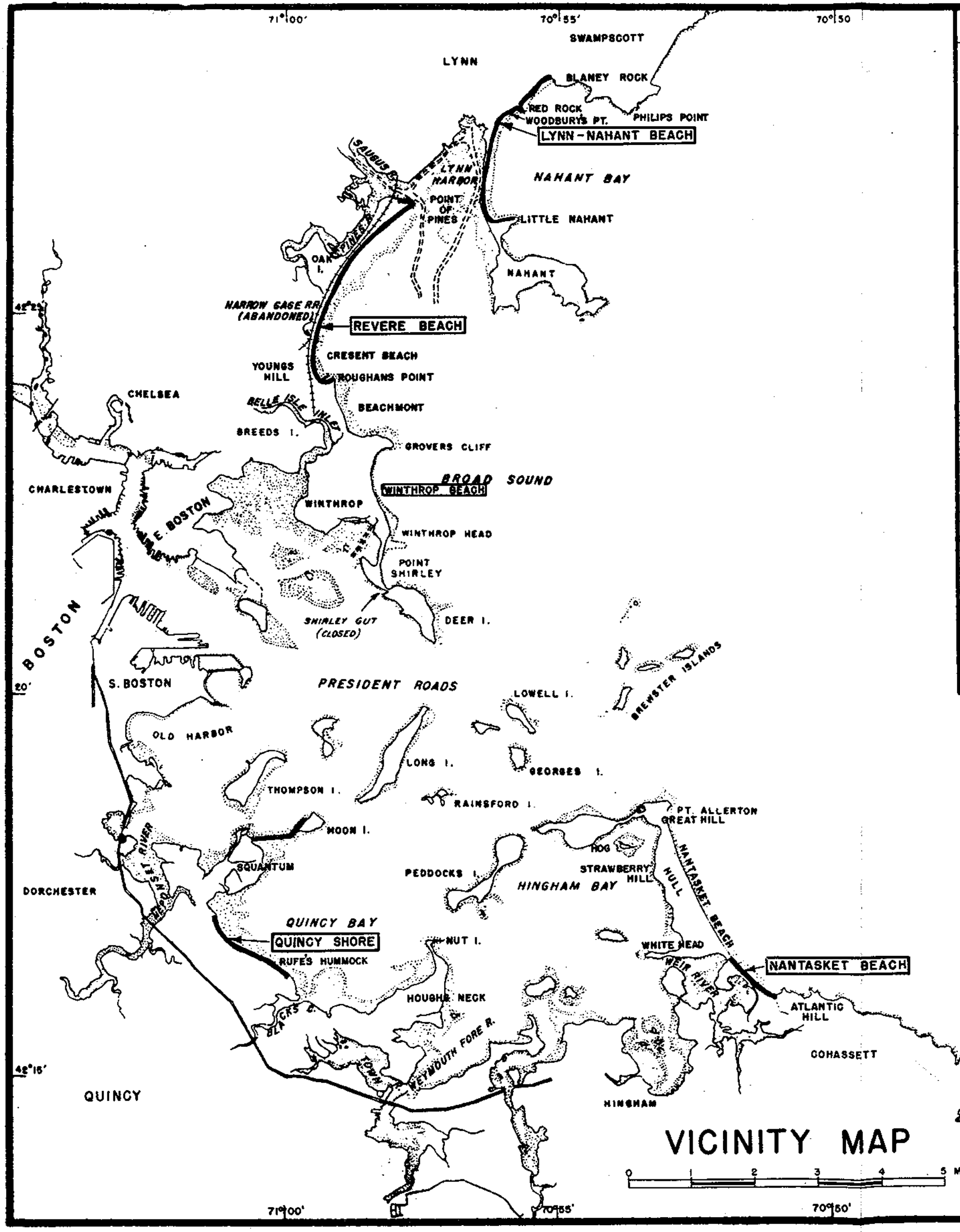
The non-federal public benefit from private property increase is thus $2,750 and the private benefit is $4,470.

3. Total Benefits. - The total benefits evaluated herein are as follows:

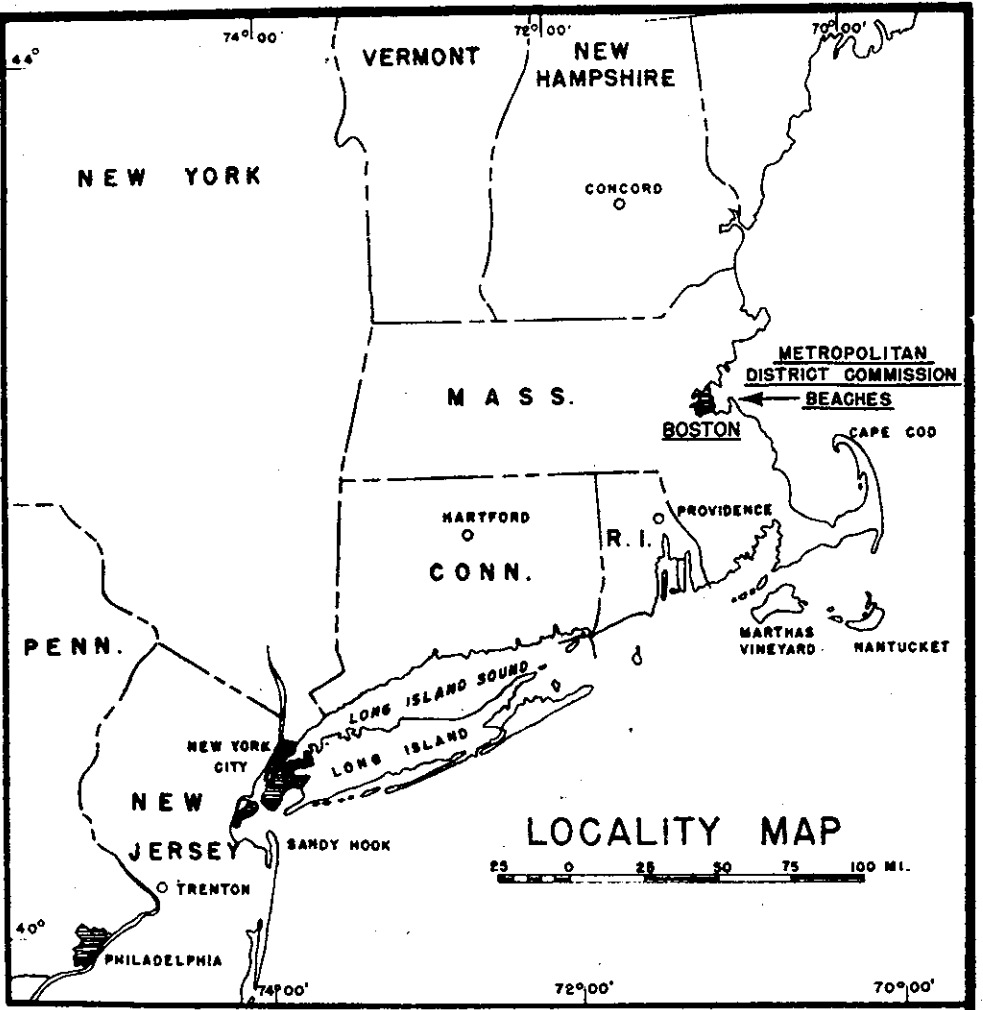
	Federal	Non-Federal Public	Private	Total
Direct Damages Prevented	$ 0	$14,050	$ 0	$14,050
Recreational Benefits	0	23,250	4,470	27,720
Totals	$ 0	$37,300	$4,470	$41,770

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY



VICINITY MAP



LOCALITY MAP

To Accompany Report Dated: June 1, 1949.

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

DRAWN BY:

TRACED BY: R.J.G.

CHECKED BY: W.C.J.

SUBMITTED BY: William C. Jackson
ENGINEER

APPROVED:
CHIEF, R.& H. OPER. DIV.

METROPOLITAN DISTRICT COMMISSION BEACH EROSION STUDY

LOCATION OF METROPOLITAN DISTRICT BEACHES, MASS.

APPROVED: James H. Stratton
COL. DIVISION ENGINEER

DATE: MAY 27, 1949.

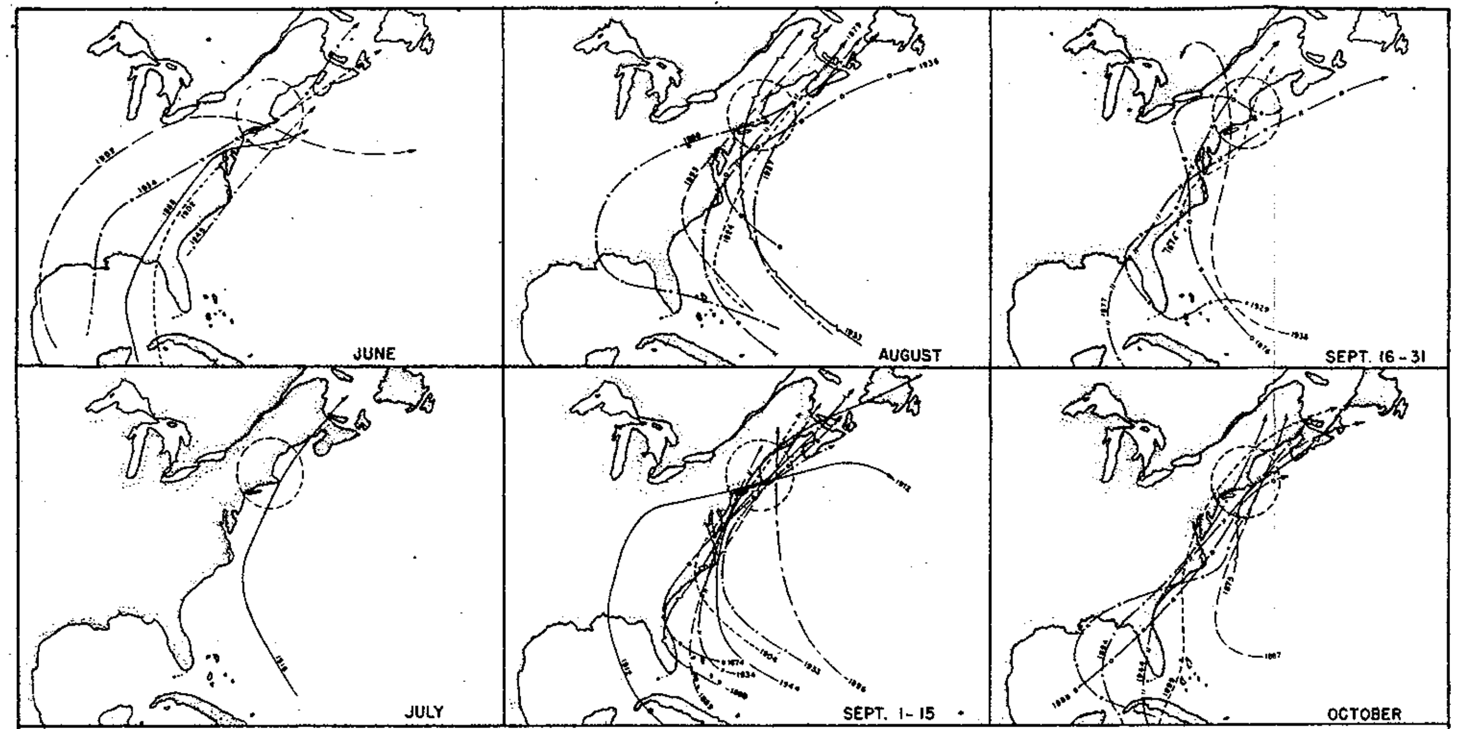
SCALE AS SHOWN

DRAWING NUMBER
45 F-15-2

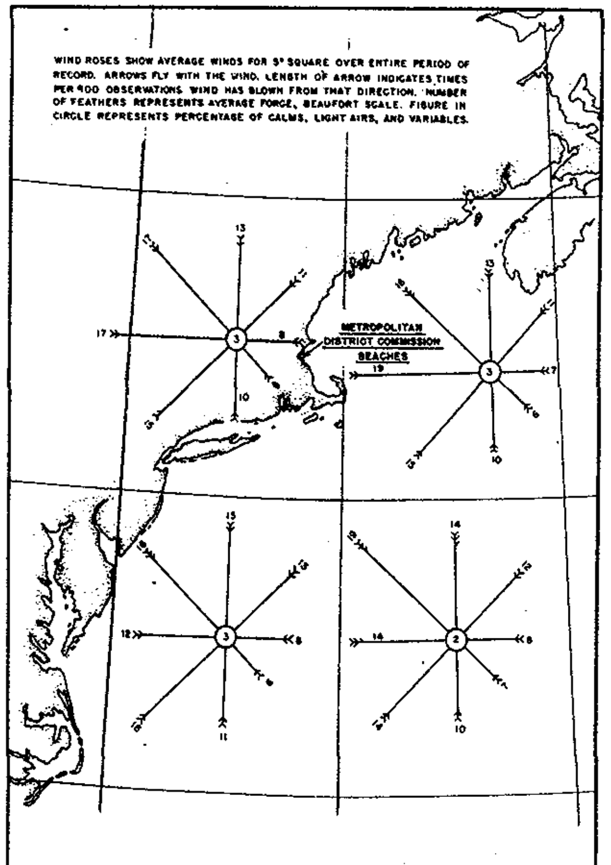
PLATE I

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY

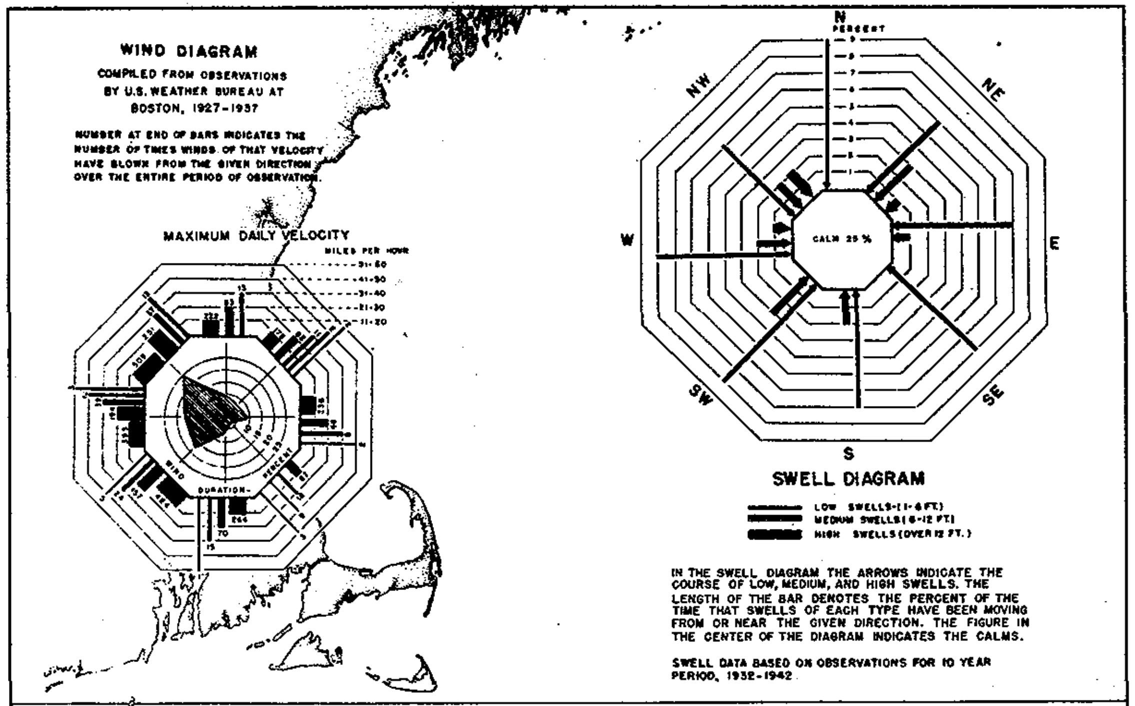


PATHS OF TROPICAL STORMS OF HURRICANE INTENSITY



WIND ROSES SHOW AVERAGE WINDS FOR 5° SQUARE OVER ENTIRE PERIOD OF RECORD. ARROWS FLY WITH THE WIND. LENGTH OF ARROW INDICATES TIMES PER 100 OBSERVATIONS WIND HAS BLOWN FROM THAT DIRECTION. NUMBER OF FEATHERS REPRESENTS AVERAGE FORCE, BEAUFORT SCALE. FIGURE IN CIRCLE REPRESENTS PERCENTAGE OF CALMS, LIGHT AIRS, AND VARIABLES.

PREVAILING WINDS



WIND DIAGRAM

COMPILED FROM OBSERVATIONS
BY U.S. WEATHER BUREAU AT
BOSTON, 1927-1937

NUMBER AT END OF BARS INDICATES THE NUMBER OF TIMES WINDS OF THAT VELOCITY HAVE BLOWN FROM THE GIVEN DIRECTION OVER THE ENTIRE PERIOD OF OBSERVATION.

SWELL DIAGRAM

LOW SWELLS-(1-6 FT.)
MEDIUM SWELLS (6-12 FT.)
HIGH SWELLS (OVER 12 FT.)

IN THE SWELL DIAGRAM THE ARROWS INDICATE THE COURSE OF LOW, MEDIUM, AND HIGH SWELLS. THE LENGTH OF THE BAR DENOTES THE PERCENT OF THE TIME THAT SWELLS OF EACH TYPE HAVE BEEN MOVING FROM OR NEAR THE GIVEN DIRECTION. THE FIGURE IN THE CENTER OF THE DIAGRAM INDICATES THE CALMS.

SWELL DATA BASED ON OBSERVATIONS FOR 10 YEAR PERIOD, 1932-1942

WIND AND SWELL DIAGRAMS

To Accompany Report Dated: June 1, 1949.

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY

WIND AND SWELL DIAGRAMS
HURRICANES AND PREVAILING WINDS

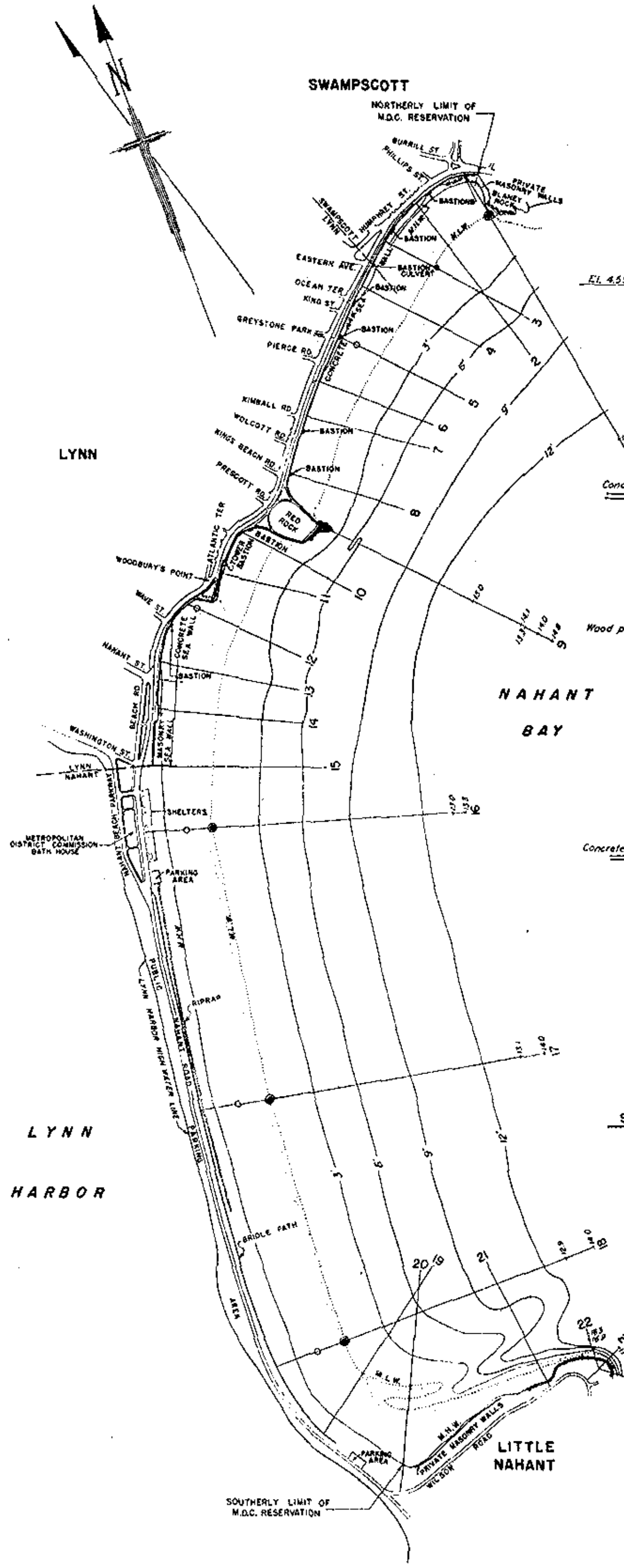
DRAWN BY
TRACED BY: R.J.G.
CHECKED BY
SUBMITTED BY
ENGINEER
APPROVED:
CHIEF, E.&.R. OPERATIONS DIV

APPROVED James H Stratton
COL. DIVISION ENGINEER
DATE MAY 27, 1949.

SCALE AS SHOWN

DRAWING NUMBER
46-F-15-2

PLATE 2



NOTES

Shorelines and offshore depths are from a survey by the Corps of Engineers, Oct.-Dec. 1945 and May 1946.

Profiles are indicated by solid lines, numbered 1 to 24.

Length of line shows length of Profile.

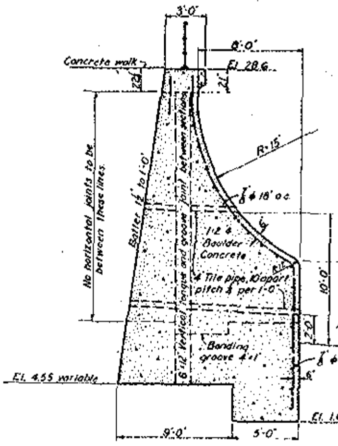
Figures indicate depth below M.L.W.

Location of points at which samples were taken indicated by ○

Location of points at which hand probings were made indicated by ●

Nahant Road and adjacent Public Parking Area shown as they existed at time of survey in 1945-46. They were reconstructed in summer of 1947 and location of road and parking area were interchanged.

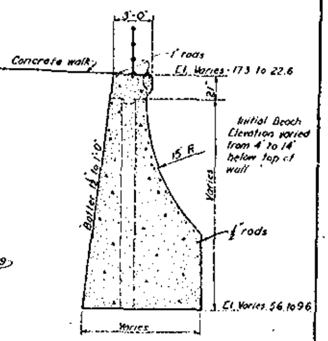
100' 0 100' 300' 500' 700' 900' 1100' 1300' 1500'
SCALE IN FEET



TYPICAL SECTION OF WALL

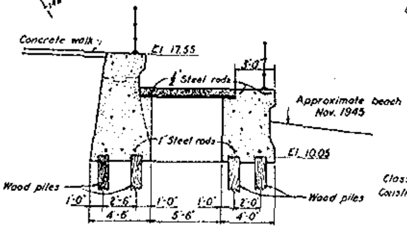
NORTH OF PROFILE NO. 1
SCALE: 1/4" = 1'-0"

4' 0' 4' 8'



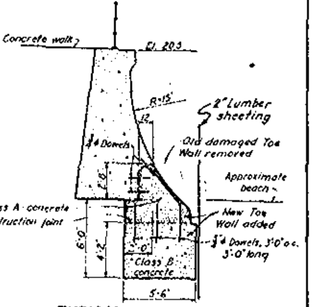
TYPICAL SECTION OF ORIGINAL WALL

PROFILES NO. 1 TO 8
SCALE: 1/4" = 1'-0"



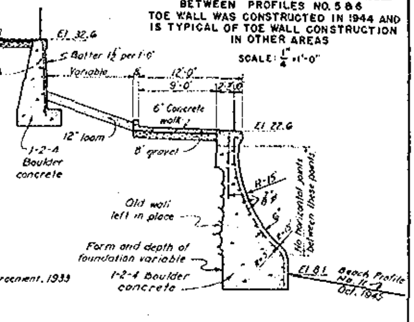
SECTION THRU RAMP BASTION

NEAR PROFILE NO. 3
TYPICAL OF SECTION SUPPORTED ON PILES
SCALE: 1/4" = 1'-0"



TYPICAL SECTION OF WALL

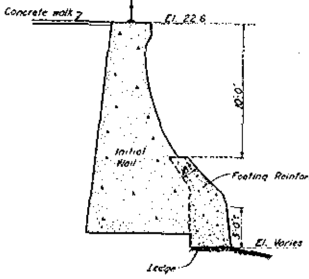
BETWEEN PROFILES NO. 5 & 6
TOE WALL WAS CONSTRUCTED IN 1944 AND IS TYPICAL OF TOE WALL CONSTRUCTION IN OTHER AREAS
SCALE: 1/4" = 1'-0"



TYPICAL SECTION OF WALL

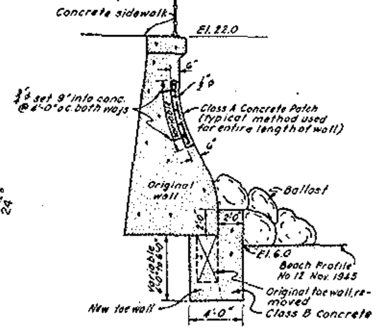
SECTION AT PROFILE NO. 11 AND TYPICAL OF ORIGINAL WALL AROUND WOODBURY'S PT.
SCALE: 1" = 6'-0"

6' 0 6' 12'



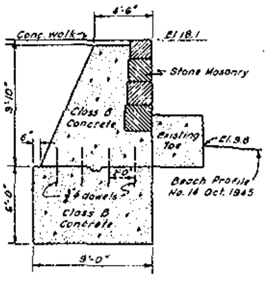
SECTION SHOWING REINFORCED FOOTING

TYPICAL OF WALL SECTION AROUND RED ROCK CONSTRUCTED IN 1933
SCALE: 1/4" = 1'-0"


Concrete sidewalk
El. 22.0
1/2" ϕ set 9" into conc. @ 4'-0" o.c. both ways
Class A Concrete Patch (typical method used for entire length of wall)
Original wall
Ballast
El. 6.0 Beach Profile No. 12 Nov. 1945
Original toe wall, removed
Class B Concrete
New toe wall
4'-0"

TYPICAL SECTION OF WALL

SECTION AT PROFILE NO. 12 SHOWING REPAIRS AND TOE WALL CONST. IN 1941
TYPICAL OF WALL SOUTH OF WOODBURY'S PT.
SCALE: 1/4" = 1'-0"



TYPICAL SECTION OF WALL

SHOWING TYPICAL SECTION OF 250 FEET OF MASONRY WALL REBUILT IN 1941
EXISTING TOE WALLS EXTEND TO NAHANT ST
SCALE: 1/4" = 1'-0"

To Accompany Report Dated: June 1, 1949

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS

DRAWN BY
TRACED BY
CHECKED BY
SUBMITTED BY
APPROVED
CHIEF E & S DIV

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY

EXISTING STRUCTURES

LYNN-NAHANT BEACH
MASSACHUSETTS

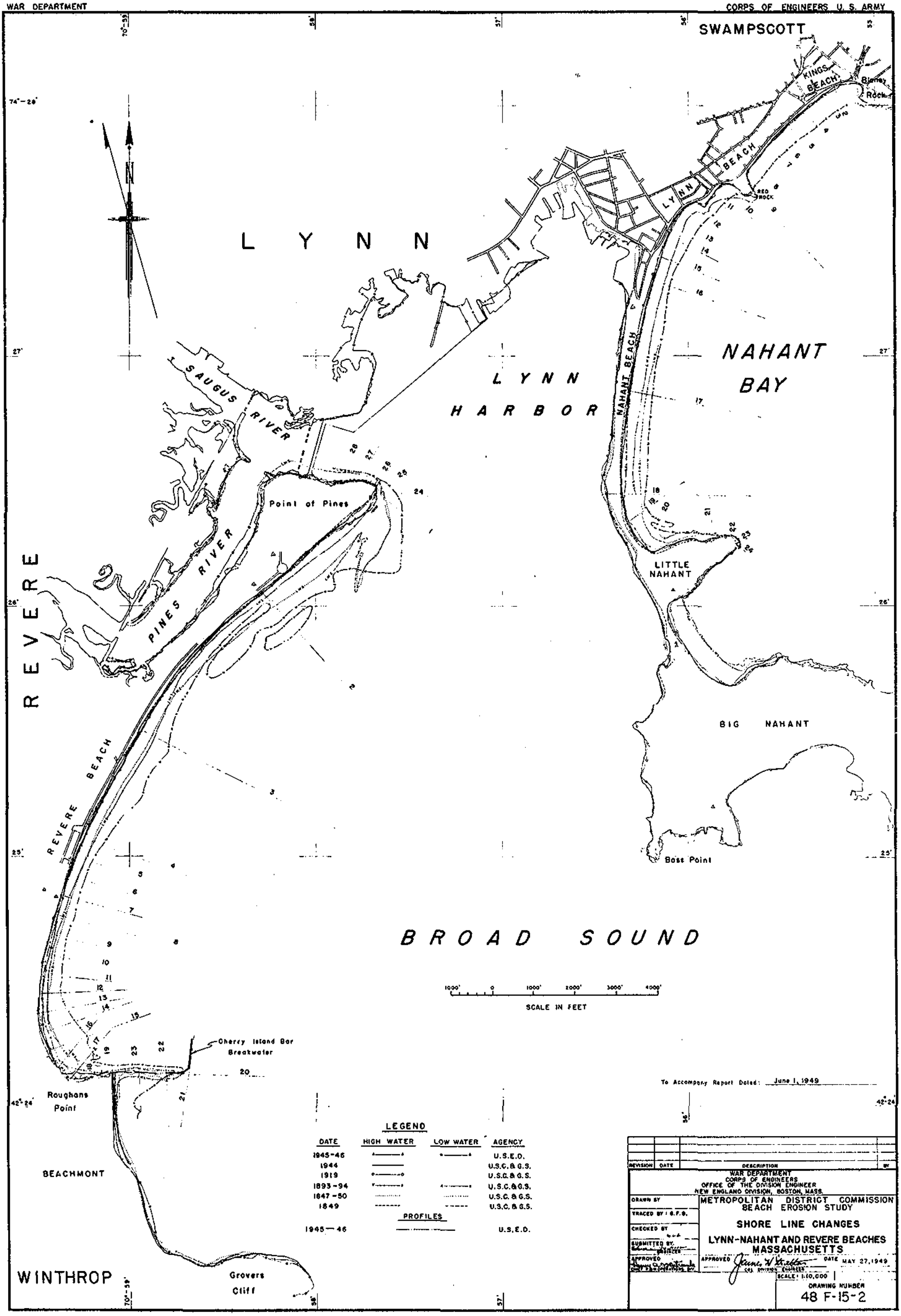
APPROVED
COL. DIVISION ENGINEER
DATE MAY 27, 1949

SCALE AS SHOWN
DRAWING NUMBER
47 F-15-2

PLATE A-1

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY



To Accompany Report Dated: June 1, 1949

REVISION	DATE	DESCRIPTION	BY

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

DRAWN BY
TRACED BY: G.F.G.
CHECKED BY
SUBMITTED BY
APPROVED

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY

SHORE LINE CHANGES

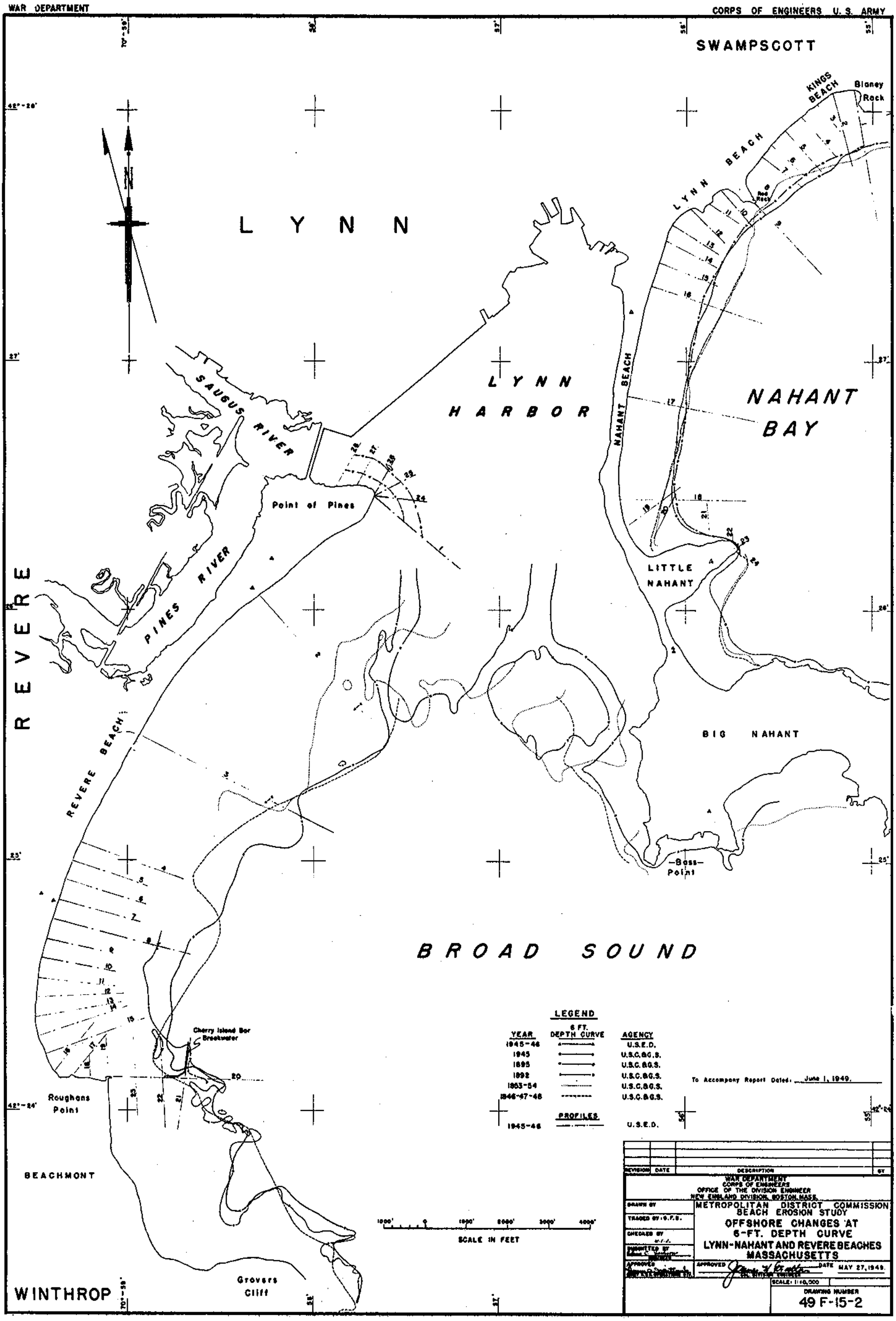
LYNN-NAHANT AND REVERE BEACHES
MASSACHUSETTS

APPROVED James H Stratton
COL. DIVISION ENGINEER
DATE MAY 27, 1949

SCALE: 1:10,000

DRAWING NUMBER
48 F-15-2

PLATE A-2



LEGEND

YEAR	6 FT. DEPTH CURVE	AGENCY
1945-46	·—·—·	U.S.E.D.
1945	•——•	U.S.C.&G.S.
1895	•——•	U.S.C.&G.S.
1892	•——•	U.S.C.&G.S.
1853-54	········	U.S.C.&G.S.
1846-47-48	--------	U.S.C.&G.S.

PROFILES

1945-46	—·—·—	U.S.E.D.

To Accompany Report Dated: June 1, 1949.

REVISION	DATE	DESCRIPTION	BY

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

DRAWN BY
TRACED BY: G.F.S.
CHECKED BY M.F.J.
SUBMITTED BY
APPROVED

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY
OFFSHORE CHANGES AT
6-FT. DEPTH CURVE
LYNN-NAHANT AND REVERE BEACHES
MASSACHUSETTS

APPROVED DATE MAY 27, 1949.
COL. DIVISION ENGINEER

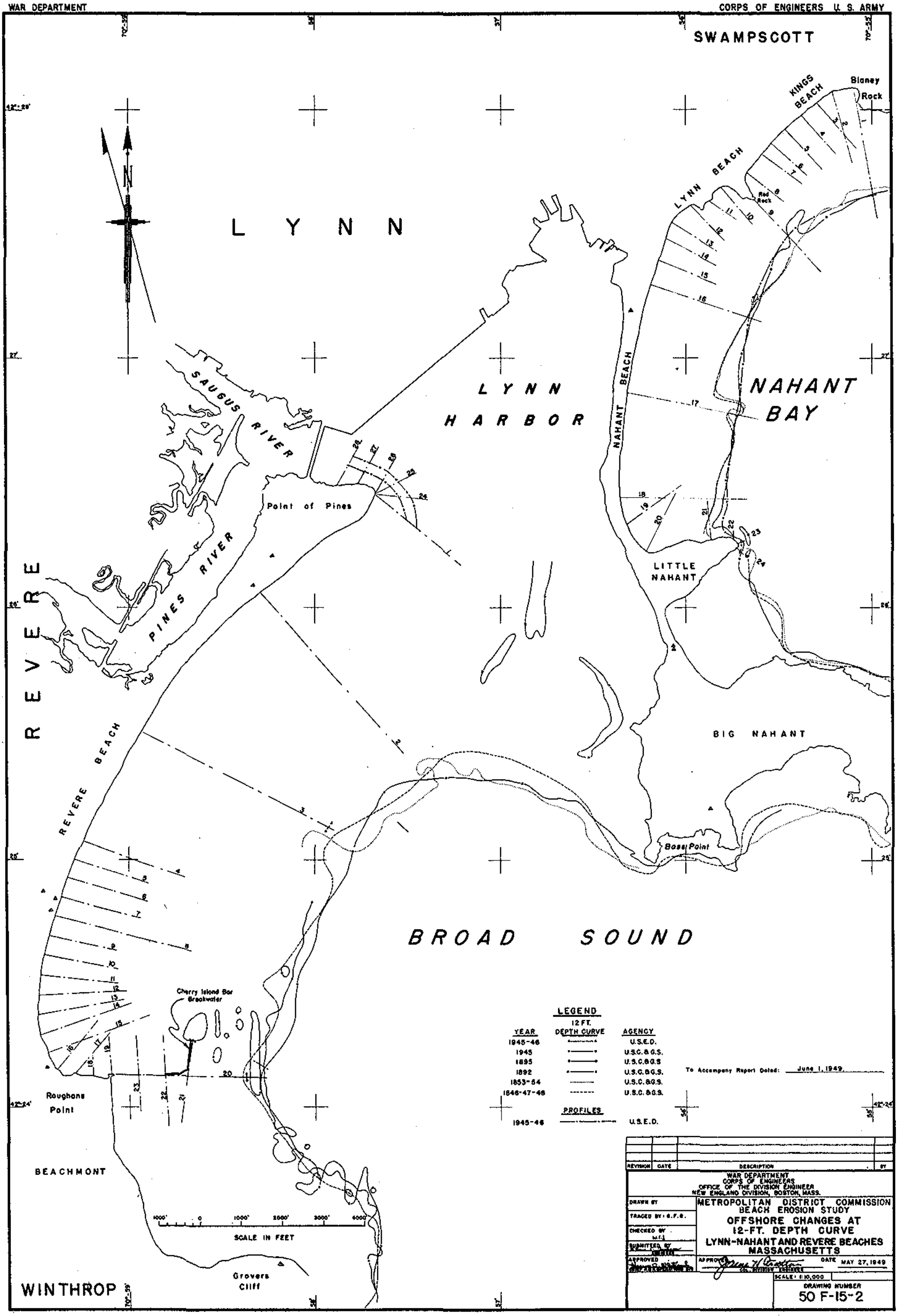
SCALE: 1:10,000

DRAWING NUMBER
49 F-15-2

PLATE A-3

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY



LEGEND

YEAR	12 FT. DEPTH CURVE	AGENCY
1945-46	········	U.S.E.D.
1945	•——•	U.S.C.&G.S.
1895	•——•	U.S.C.&G.S
1892	•——•	U.S.C.&G.S.
1853-54	········	U.S.C.&G.S.
1846-47-48	- - - -	U.S.C.&G.S.

PROFILES

1945-46	—·—·—	U.S.E.D.

To Accompany Report Dated: June 1, 1949.

REVISION	DATE	DESCRIPTION	BY

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

DRAWN BY

TRACED BY: G.F.G.

CHECKED BY M.F.J.

SUBMITTED BY

APPROVED

METROPOLITAN DISTRICT COMMISSION BEACH EROSION STUDY

OFFSHORE CHANGES AT 12-FT. DEPTH CURVE

LYNN-NAHANT AND REVERE BEACHES MASSACHUSETTS

APPROVED James H. Stratton
COL. DIVISION ENGINEER

DATE MAY 27, 1949

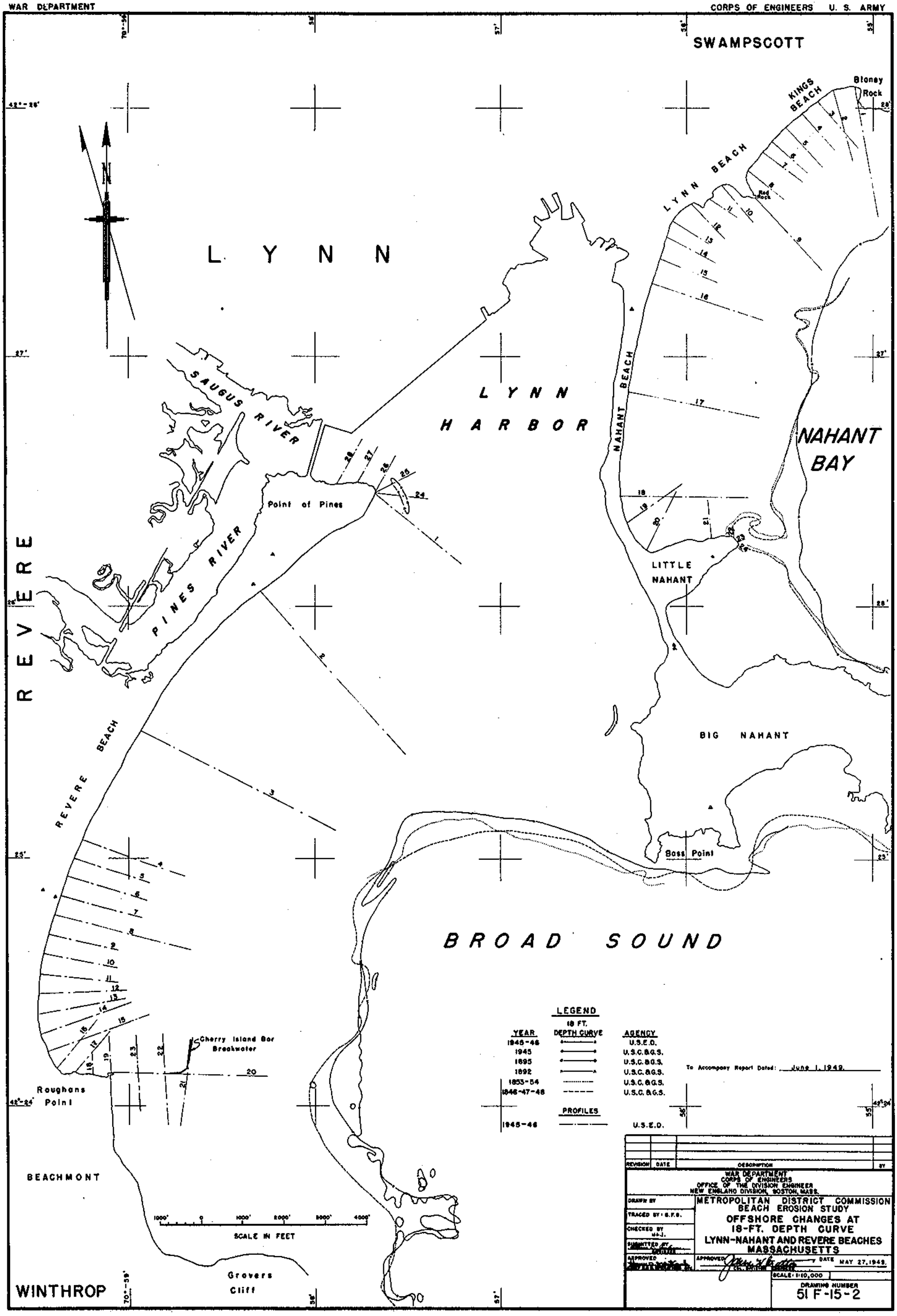
SCALE: 1:10,000

DRAWING NUMBER
50 F-15-2

PLATE A-4

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY



LEGEND

YEAR	18 FT. DEPTH CURVE	AGENCY
1945-46	●———▲	U.S.E.D.
1945	●———●	U.S.C.&G.S.
1895	●———◆	U.S.C.&G.S.
1892	▸———▴	U.S.C.&G.S.
1853-54	··········	U.S.C.&G.S.
1846-47-48	– – – – –	U.S.C.&G.S.

PROFILES

1945-46	—·—·—	U.S.E.D.

To Accompany Report Dated: June 1, 1949.

REVISION	DATE	DESCRIPTION	BY

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

DRAWN BY
TRACED BY: G.F.G.
CHECKED BY M.J.
SUBMITTED BY
APPROVED

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY
OFFSHORE CHANGES AT
18-FT. DEPTH CURVE
LYNN-NAHANT AND REVERE BEACHES
MASSACHUSETTS

APPROVED John W. Moore DATE MAY 27, 1949.

SCALE: 1:10,000

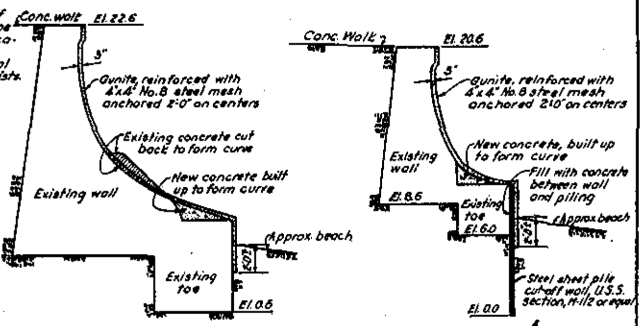
DRAWING NUMBER
51 F-15-2

PLATE A-5

NOTE

Existing toe does not extend entire length of wall and varies in shape and size at various locations.

Sections show typical conditions where toe exists.


Conc. walk
El. 22.6
3"
Gunite, reinforced with 4"x4" No. 8 steel mesh anchored 2'-0" on centers
Existing concrete cut back to form curve
New concrete built up to form curve
Existing wall
Approx. beach
Existing toe
El. 0.6
Conc. Walk
El. 20.6
3"
Gunite, reinforced with 4"x4" No. 8 steel mesh anchored 2'-0" on centers
New concrete, built up to form curve
Existing wall
Fill with concrete between wall and piling
El. 8.6
Existing toe
El. 6.0
Approx. beach
Steel sheet pile cut-off wall, U.S.S. Section, M-112 or equal
El. 0.0

SECTION NEAR PROFILE 8

TYPICAL TREATMENT WHERE CUTOFF WALL IS NOT REQUIRED

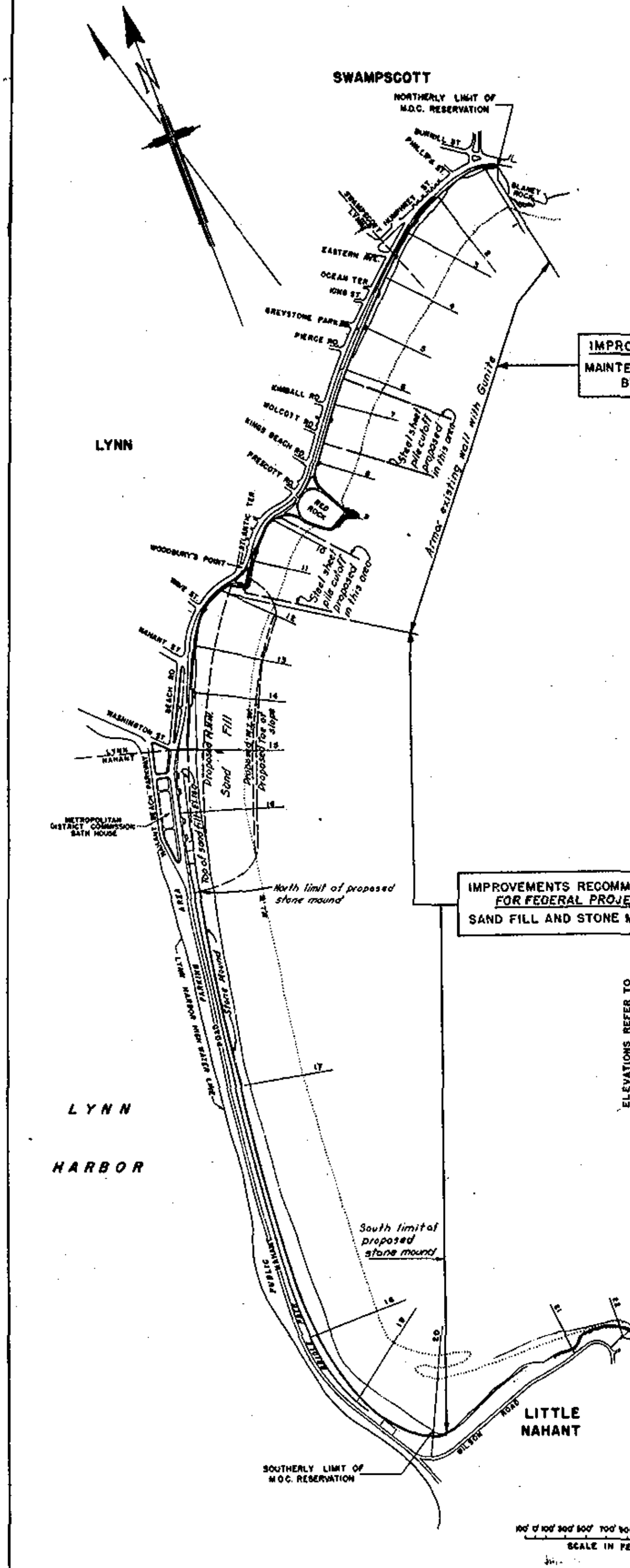
SECTION AT PROFILE 7

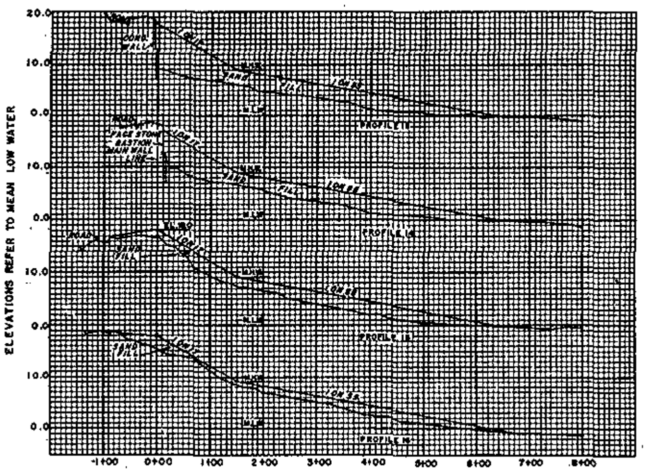
TYPICAL TREATMENT WHERE CUTOFF WALL IS REQUIRED

DETAILS OF GUNITE ARMOR AND STEEL SHEET PILE PROTECTION

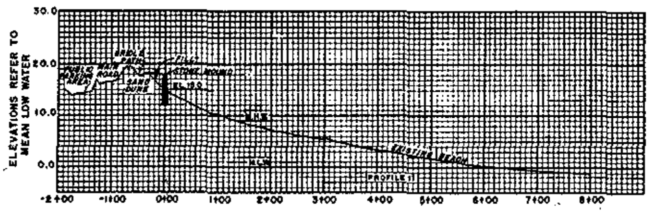
FOR EXISTING CONCRETE WALL

SCALE $\frac{1}{4}$"=1'-0"



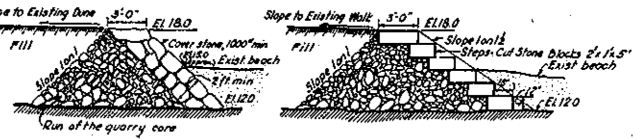


TYPICAL SECTIONS OF SAND FILL



LOCATION OF STONE MOUND

TYPICAL SECTION AT PROFILE 17



TYPICAL SECTION

STEP SECTION

DETAILS OF STONE MOUND

SCALE $\frac{1}{4}$"=1'-0"

4' 0 4' 8'

NOTE

Steps required at 25 locations to provide access to fireplaces and tables at base of sand dunes.

NOTES

All elevations refer to Mean Low Water.

Beach profiles from survey by Corps of Engineers, Oct-Dec. 1945 and May 1946.

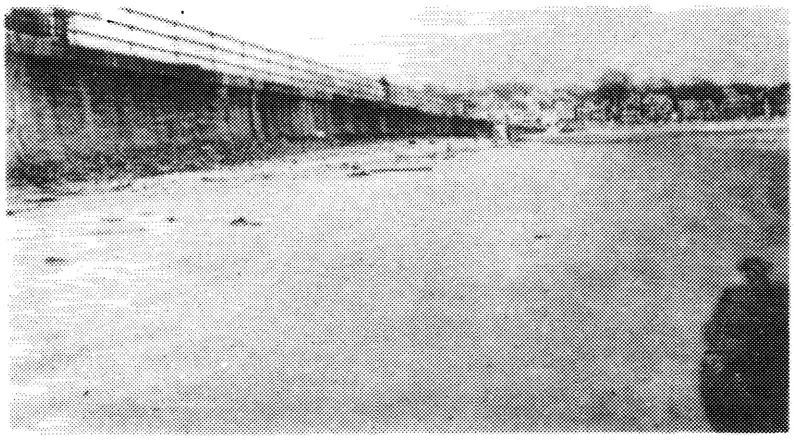
Nahant Road and Public Parking Area was reconstructed in 1947, and relocated so that Public Parking Area is adjacent to sand dune.

To Accompany Report Dated: June 1, 1949

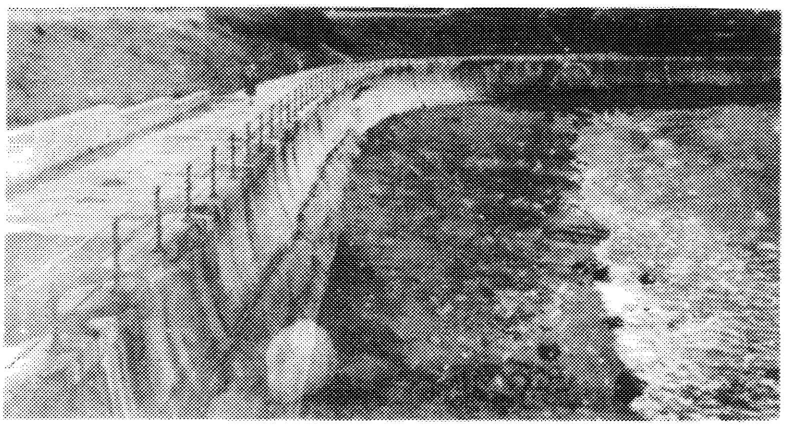
WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS

DRAWN BY P.D.M.	METROPOLITAN DISTRICT COMMISSION BEACH EROSION STUDY
TRACED BY P.D.M.	PLANS OF PROTECTION
CHECKED BY	LYNN-NAHANT BEACH
SUBMITTED BY	MASSACHUSETTS
APPROVED	APPROVED COL., DIVISION ENGINEER DATE MAY 31, 1949
	SCALE AS SHOWN
	DRAWING NUMBER 52 F-15-2

PLATE NO. A-6

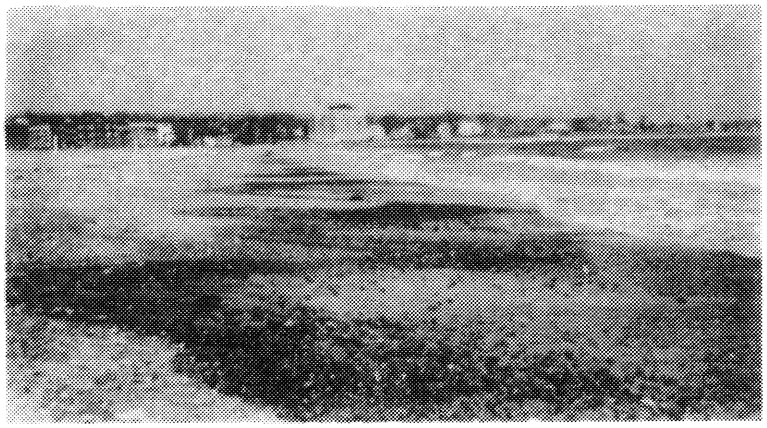


Looking northeast toward Profile 4, showing north-end of Lynn Beach. Stone deposit occurs only in this area.

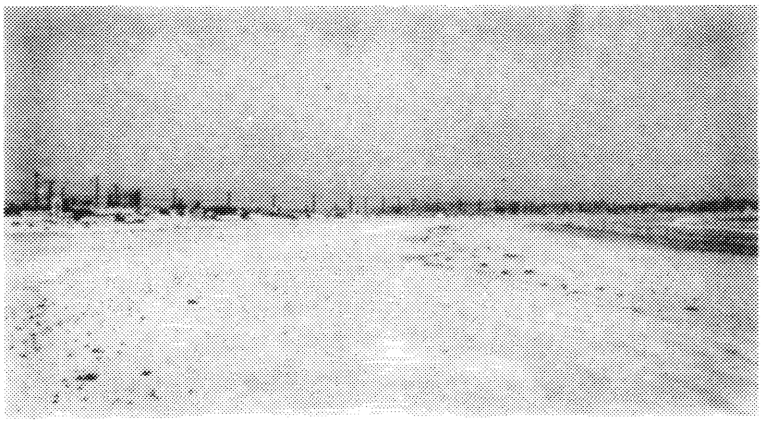


Looking northeast from Tower Bastion near Profile 11, showing wall and beach at base of Red Rock. Note exposed reinforcing

Metropolitan District Commission Study
BEACH CONDITIONS
LYNN-NAHANT BEACH, MASS.
Fig. A-1

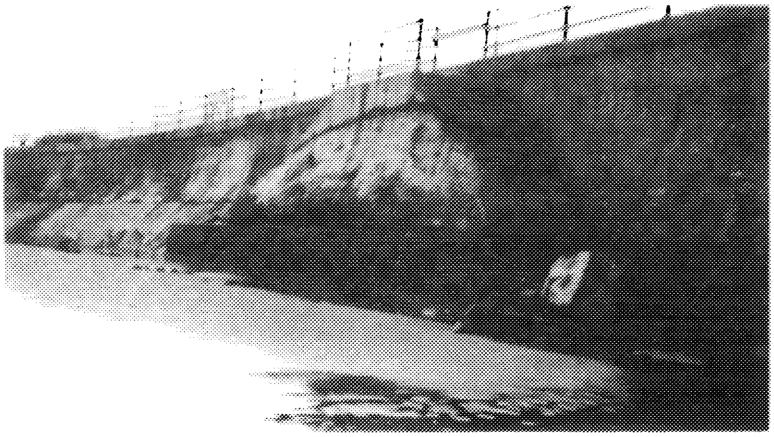


Looking north from Profile 16, showing stony beach in bathhouse area.

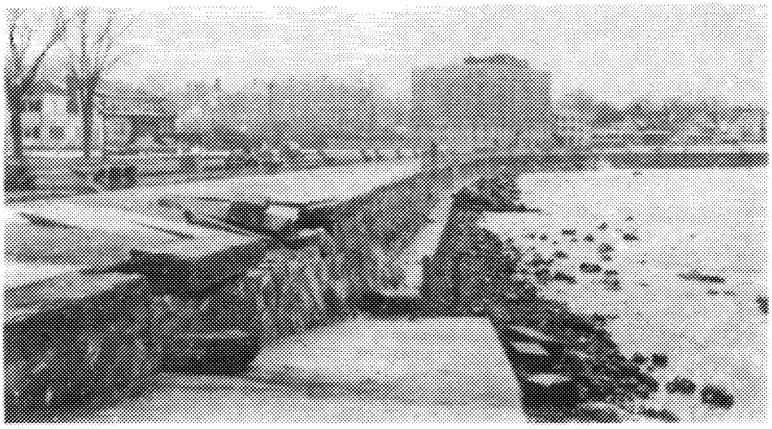


Looking north from Profile 19, showing south end of Nahant Beach. Note fireplaces at toe of dune.

Metropolitan District Commission Study
BEACH CONDITIONS
LYNN-NAHANT BEACH, MASS.
Fig. A-2



Steps at Profile 8 prior to reconstruction. Typical of damage experienced by wall at all locations.



Wall northeast of bastion at Profile 14 after northeast storm of 28-30 November 1945

Metropolitan District Commission Study
DAMAGED WALLS
LYNN-NAHANT BEACH, MASS.
Fig. A-3